DO NOT REMOVE FROM LIBRARY

JOURNAL

OF THE

New England Water Works Association

VOLUME XXXVI

1922

PUBLISHED BY

THE NEW ENGLAND WATER WORKS ASSOCIATION

715 TREMONT TEMPLE, BOSTON, MASS.

The four numbers composing this volume have been separately copyrighted in 1922 by the New England Water Works Association.

The Fort Hill Press
SAMUEL USHER
BOSTON, MASSACHUSETTS

INDEX.

59379

READ THE ADVERTISEMENTS

IN THE BACK OF THIS JOURNAL

The ADVERTISERS are doing THEIR PART in supporting the Journal and the Association

LET US—in fairness—DO OUR PART by registering a direct and unmistakable response

MORE ADVERTISEMENTS MEAN A BETTER JOURNAL

Boost the Association by responding to our present advertisers, and by helping to get others

Table of Contents.

New England Water Works Association

ORGANIZED 1882.

Vol. XXXVI. March, 1922. No. 1.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

MAKING CHLORINE AT THE POINT OF CONSUMPTION.

BY CLARENCE W. MARSH.*

[*Read September 15, 1921, at Bridgeport, Conn.*]

The modern idea is to save time. Use electric power at the point of consumption and make your product. This saves time and money. Ask the housewife who has a home with applied electricity as a servant, or the superintendent of any factory with the latest electric appliances to save labor. There is something real in the smoothness and continuity of operation in the midst of clean surroundings which always accompanies the use of electric power. It attracts the best class of labor. It reduces effort and makes labor attractive and interesting.

Finished manufactured products usually require additional work and equipment to handle, control, and prepare these products for use at the point of consumption. Attendance is required on these devices and machines for the final preparation of these products. A great deal of unnecessary work can be eliminated if the product can be made economically at the consumer's plant. It saves time, labor, equipment, and materials, and therefore real money. This is the basis for your consideration of making chlorine by the consumer.

The growing demands for sterilizing and purifying reagents for water and sewage has caused a great expansion of the use of chlorine, the cheapest and most efficient medium. Its commercial forms are bleach, or chloride of lime, and liquid chlorine. In the first case, lime acts as the carrier of the chlorine and the bleach is shipped in expensive steel drums which are non-returnable. In the second case, the chlorine gas is compressed and liquified by refrigeration and the liquid chlorine is shipped in steel cylinders under high pressure, and these cylinders must be returned to the manufacturer.

Why not make the chlorine gas on the job? This is the best and most efficient way, because the chlorine is made as a gas under atmospheric pressure or less, and is immediately available for use and in exact proportion to the dosage and water pumped, without the need of further control apparatus.

* Consulting Engineer, New York

Why is it not done to a much greater extent? Up to the present time there has not been enough recognition of the basic economy of producing chlorine as wanted at the point of consumption without the necessity of tying up money in inventories, in shipments, and at the factories. There is not enough knowledge of various steps in the manufacture and distribution of chlorine in the possession of the consumer. Manufacturers of bleach and chlorine have shown very commendable zeal in the sale of their products, and have helped the consumer by placing in his hands excellent devices for the control and dosage of chlorine to water. There has not appeared an efficient enough machine at reasonable cost in the market until recently, to make chlorine in small quantities for the small consumer. These machines usually are too big in size and involve considerable expense for space and maintenance.

Recently there has been developed an electrolytic cell battery which takes very little space and is a unit, not several units, which means few parts and a very low cost of repairs, renewals, and depreciation. In addition to this the efficiency with which power is used makes the cost of production of chlorine 20 per cent. less than present methods and cuts the waste of materials used in cells to less than one half that which formerly seemed necessary. It places a more efficient machine in the hands of the small consumer than the largest manufacturers of chlorine use to-day. Heavy investments in expensive equipment which has not been depreciated and amortized prevents manufacturers acting promptly in adopting more efficient machinery, because it means accepting a heavy loss now when he can least afford it.

Let us analyze the fundamental reasons why it is cheaper to manufacture chlorine at the point of consumption rather than at a distant point. It challenges the older methods of manufacture and distribution under modern conveniences and conditions with electric power at reasonable rates available to every community in the land and the necessity to eliminate every possible expense, such as transportation, the many steps to put the product in the form required for transportation and then re-transforming to the desired form used by the consumer, and many overhead expenses accompanying these unnecessary steps, including the manufacturer's profit.

The consumer will use four times as much bleach as chlorine. Bleach contains 35 per cent. available chlorine when it leaves the factory, but only 25 per cent. or less can be counted upon because of deterioration in storage and the losses of chlorine in making solutions of chloride of lime. We will use this figure in making comparisons. Present market prices will be used. The prices are approximately 50 per cent. above pre-war prices for bleach, and approximately the same as pre-war prices for liquid chlorine. Ultimately all prices will probably be equal to pre-war prices.

What is the cost of materials at the point of consumption for bleach, liquid chlorine, and chlorine made at the point of consumption?

Bleach costs $42 a ton at the factory. Freight averages $4 per ton, and cartage to the point of consumption about $2, or a total for transportation of $6. Containers are included in the price and must be disposed of by the consumer. The cost for the equivalent of a ton of chlorine is 4 × $48 = $192.

Liquid chlorine costs $160 a ton at the factory for the small consumer, and probably more unless under contract. Freight or, rather, express, because of the small number of cylinders and the necessity of keeping small quantities on hand owing to the hazard and the capital tied up in inventories, will cost at least at the rate of $0.80 per 100 lb. weight. There is 100 lb. of container for every 100 lb. of chlorine, and this additional 100 lb. must be returned by freight or express.

Then 3 × $0.80 (including cartage if by freight) = $2.40 per 100 lb. chlorine, or $48 per ton. Containers will call for an investment of $500 for the average-size consumer, which is in the form of a deposit to cover the value of the cylinders, and probably the wear and tear on the cylinders will devolve on the consumer. Call it "interest and depreciation" on $500 at 30 per cent. for a consumption of 50 lb. chlorine daily. $\$\frac{150}{9} = \$16$ per ton of chlorine. The total cost per ton of chlorine is $224.

The production of chlorine at the point of consumption with Marsh cells calls for the following materials and power:

Salt used equals 4 lb. per 1 lb. of chlorine, 4 tons at $5 = $20 per ton of chlorine. Freight carloads lots, $4 per ton and cartage $2 per ton. Total for salt = $44. This considers that the caustic soda liquor is either sold or thrown away. If the salt in the liquor is recovered, then the cost will be $22 per ton of chlorine.

Graphite, diaphragms, and depreciation of all other materials in the electrolytic equipment will cost, including the labor entering into these materials, $10 per ton of chlorine. The freight or express is included. The amounts are very small.

Power will be based on an average rate of 2c. kw.-hr. A difference of 1c. kw.-hr. above or below this will affect the cost by $25 per ton. The power used per pound of chlorine is at the rate of $1\frac{1}{4}$ kw.-hr. per pound (2 500 kw.-hr.) per ton. At 2c. per kw.-hr. cost = $50 per ton of chlorine. The total cost for all materials will be $104, or $82 per ton, depending on whether the salt is recovered from the caustic liquor or not.

What is the cost of labor and attendance? In all cases material must be handled by labor, and the equipment necessary must receive some attention and must be frequently inspected. The use of bleach, liquid chlorine, and the making of chlorine is no exception.

Bleach comes in steel drums weighing about 800 lb. each. These drums are stored away until ready to use. Chloride of lime solutions for application to water are made by mixing the bleach with water and allowed to settle for clear solutions before being used. This solution is then ready to be fed by some control device in proper proportions and at the rate re-

quired by the pumping rate of water. Labor and equipment is required for handling these solutions. On account of the dust and smell, the space required must be partitioned off from other building space, or separate buildings used. This makes it less convenient to superintend the operations and increases the cost of attendance if the control apparatus is located in the same space as the mixing.

Liquid chlorine comes in 100-lb. steel cylinders which contain 100 lb. of chlorine. A certain number of these cylinders is kept in storage, ready for connecting up to the control apparatus. Shipments of cylinders are made frequently, and considerable labor is involved in handling the cylinders and in connecting and disconnecting them. On account of the hazard of storing high-pressure chlorine, separate buildings are recommended, thus removing dangerous conditions to firemen in case of fire. This means extra cost for buildings and attendance, but the precautions against unnecessary risks are unavoidable. Control apparatus does not last, and frequent replacements of expensive parts must be made if the apparatus is to function properly and leaks be avoided.

Chlorine gas is made by electrolyzing brine solutions. Direct current of electricity is passed through these solutions in containers which support the electrodes. Acheson graphite is used as the anode or the positive pole, and steel plates which are perforated for the negative pole. A diaphragm of asbestos cloth or paper is placed between the electrodes, and is usually supported by the negative plate or cathode. The chlorine gas is collected in the top of the container holding the brine and is taken away under a slightly reduced pressure through a water ejector, and distributed to the water to be sterilized. The mixture of caustic soda and salt solution which percolates through the diaphragm is collected in containers outside of the cell proper. Hydrogen is also evolved at the cathode and may be collected or wasted in the air. One or more cells are used, and this battery, which is a unit, is placed in one box or container or pit with partitions between the cells. Fifty lb. chlorine requires a pit or box $2\frac{1}{3}$ ft. by $2\frac{2}{3}$ ft. inside; 300 lb. chlorine daily, $4\frac{2}{3}$ ft. by 5 ft.; 1 000 lb. chlorine, $4\frac{2}{3}$ ft. by 15 ft. 8 in.; $1\frac{1}{4}$ kw.-hr. per 1 lb. chlorine is required. If power is 2c. or under, and it is desirable to keep the apparatus very small, then with a rate of $1\frac{2}{3}$ kw.-hr. per 1 lb. chlorine the apparatus can be reduced to ONE-HALF these sizes. This indicates the small space required. The cells can be placed in any laboratory, and moved around in the battery box wherever wanted, or can be permanently located in the floor. In an operating position the battery will be about 12 in. high above the floor line. If placed in a box, the battery will be 3 ft. high.

An assurance of the very best care and inspection is guaranteed when an apparatus is located in a laboratory or in the same room with other machinery which must be inspected and with a minimum cost for attendance. The tops of the cells are tight, and the gas is evolved at a reduced pressure and withdrawn as fast as made and ejected to the water to be

sterilized through water ejectors. As soon as the current is turned off the production of chlorine ceases. Chlorine is made in proportion to the dosage required and according to the rate of water pumped by changing the amount of current automatically. Chlorine is produced proportionally to the electric current flowing through the electrolytic battery.

Electric rectifiers consisting of small vacuum bulbs such as mercury bulb rectifiers used in charging automobile storage batteries are being perfected to transform the electric current to direct current at a high efficiency of transformation. These rectifiers offer simplicity and a minimum attendance for the smaller capacity plants. Small motor generator sets with spare machines will take care of the larger capacity outfits. These electrical devices or machines are standard, and, as all know, are very reliable converters demanding very little attention.

Where electric current is generated at the plant it can be generated as direct current, thus saving the loss of transformation. In some cases steam is used for pumping, and then electric current can be produced very cheaply through the use of small steam-turbine-generator units.

The salt may be stored in a dry form on the floor or in bins, or, better, under brine in outside wood or concrete tanks, when brine will always be available. This brine is mixed with a little soda ash and caustic liquor from the cells, to settle out calcium and magnesia salts. It is done in batches in small wood or concrete tanks located inside the building, and if of concrete made a part of the building. The brine is made neutral by adding small amounts of acid, and is ready to feed to the battery through a level control box and automatic floats in the cells.

We must judge the costs of attendance by the convenience of inspection and the continuity and reliability of the respective methods. In general it may be assumed equal in all cases. Mechanical devices can be made very reliable. Electrical machinery had advantages which are not denied. Users of each type seem to be satisfied as regards these features.

For small plants the item of attendance is very important and in the case of producing chlorine, using liquid chlorine or bleach, even the minimum attendance amounts to as much as all the other costs put together. Where regular attendance is insisted upon or furnished, then it is by far the largest item of costs. In the larger plants this item of attendance is relatively a smaller cost.

It would seem that an electrical appartus for the smaller plants would find considerable favor on account of the smaller cost of production for materials and the convenience of having the apparatus placed in a laboratory or in the same room with other apparatus, insuring a maximum attention at a minimum cost and without hazard and obnoxious conditions.

Interest and depreciation is an item of expense which must be considered in each case. The life of an apparatus varies under differing conditions, and estimates of this item of cost will vary. Nevertheless,

equipment must be constantly renewed, and it is essential that it be well taken care of and that the parts are inexpensive.

Control apparatus for bleach solutions are usually crude devices and subject to rapid deterioration and need a great deal of attention to prevent irregularity of feed due to the nature of the corrosive liquid and deposits of lime, etc. The control apparatus, however, is usually made up of comparatively inexpensive parts, which probably makes this apparatus the cheapest to maintain. For a 50-lb. chlorine daily feed for interest and depreciation the expense per ton of chlorine would be approximately $500 at 50 per cent. $\$\frac{250}{9}$ tons = $28 per ton of chlorine made available.

For liquid chlorine very satisfactory control apparatus has been designed. The parts, however, are made of expensive metals and they are subject to very severe conditions. The high cost of machinists' labor and the necessity to make renewals of costly silver fittings makes the charges for deterioration fairly expensive. Some estimates vary from two years' to five years' life. Apparatus must be installed in duplicate for this reason, which makes it more costly. For a 50-lb. plant approximately $1 000 at 33 per cent. interest and depreciation would mean $\$\frac{330}{9}=\$36$ per ton of chlorine.

For producing chlorine we have already allowed for the materials and depreciation of all parts, including labor on the battery. The brine storage tanks, as in the case of bleach liquor tanks, are a part of the building and may be charged to building. There remains the depreciation on the electrical transforming apparatus which is standard and reliable, electrical machinery having a long life, and parts can be replaced at minimum cost. We have the interest on the investment of the battery to consider, however.

Interest on $1 000 at 6 per cent. for battery for 50-lb. chlorine daily	$60
Interest and depreciation, $1 000 at 12 per cent. for transforming apparatus for above	$120
Interest and depreciation, $200 at 12 per cent. for all other equipment except battery	$24

Total, $\frac{204}{9}=\$22$ per ton of chlorine produced.

Charges for interest and depreciation on buildings and storage equipments may be considered about the same, but of course if separate buildings are required in the cases where hazardous and obnoxious conditions exist, then this extra cost should be considered as against the factor of convenience and small expense entailed when the apparatus can be accommodated in a laboratory or in a room with other equipment at relatively low cost.

Overhead expenses for the purchase of materials, payment of labor, shipments of materials and containers, and the financial settlements and cost of money tied up in inventories are all factors.

Bleach would probably be shipped in less than carload lots approximately once a month. Liquid chlorine would be shipped by express twice a month. Salt would be shipped in carload lots in bulk twice in three years. The frequency of shipment may be considered as a gage of the

relative expense for these three methods, and can be assumed to be \$20 per ton for liquid chlorine, \$14 per ton of chlorine for bleach, and \$3 for the salt where chlorine is made at the point of consumption.

A credit should be allowed in the case of making chlorine when the caustic soda liquor can be used in the vicinity. It can be used in industrial centers and communities by soap concerns, laundries, and others, in the form made or by further concentration and evaporation, when the salt will be recovered and credited to the chlorine as stated. One and one-seventh pound of caustic soda is made for every pound of chlorine. The market price at present is 4c. a pound. It seems as though at least one half of this price could be obtained for the liquid caustic soda solutions. One and one-seventh lb. x 2c. = $2\frac{2}{7}$c. per pound of chlorine, or \$45.70 per ton of chlorine, to be credited.

It is apparent that from a financial standpoint there is an advantage in making chlorine at the point of consumption, and that from ONE-HALF to THREE-QUARTERS of the cost can be saved yearly. For larger plants this will be increased many fold.

A description of THE MARSH ELECTROLYTIC CELL BATTERIES, which has been referred to in the above comparisons of cost for the manufacture of chlorine at the point of consumption to the cost of using bleach or liquid chlorine for the sterilizing or purification of water and sewage, may be interesting and appropriate.

We will take, for example, the average small installation of a battery to make 50 lb. of chlorine daily. The best type for this size will be an intermediate size known as "Type 6-EC-2." Three cells in a battery will be required, but a fourth cell will be supplied for a spare. An entire duplication of apparatus is not required, as the spare unit will replace any of the others when it is necessary to renew the diaphragms once in six months to one year. The anodes once in two years or longer.

Each of these cells will produce 17 lb. of chlorine daily at a rate of approximately $1\frac{1}{16}$ kw.-hr. (D. C.) per lb. of chlorine or $1\frac{1}{4}$ kw.-hr. (A. C.) after transformation of current per pound of chlorine at the switchboard. The current used will be 260 amperes at 2.8 volts per cell, or 8.4 volts at the cells for the battery of 3 cells. This is for a period of six months. The cells are approximately $2\frac{1}{2}$ ft. long by 10 in. wide by $2\frac{1}{2}$ ft. high. In an operating position, i.e., when lowered in a box or pit, the cell is less than 12 in. above the top to the box or floor line.

If electric current is reasonable, these cells can be operated to produce 34 lb. daily per cell at a rate of $1\frac{1}{3}$ kw.-hr. (D. C.) per pound of chlorine or $1\frac{2}{3}$ kw.-hr. (A. C.). The current used will be approximately 520 amperes at 3.6 volts. This is an average for four months' operation.

If a movable battery is wanted, the cells are placed in a battery box fitted with castors. If it is not to be moved, then the cells are placed in a pit in the floor. This pit, to accomodate three cells operating and one spare,

will be $2\frac{1}{2}$ ft. wide by 5 ft. long by 2 ft. deep. The inside dimensions of the box will be the same.

The cells consist of three parts. The concrete top, which may be suspended from above and to which is attached perforated and horizontally corrugated steel plates carrying in turn several sheets of asbestos paper conforming in shape to the steel plates. The steel plates are the cathodes and the asbestos paper is the diaphragm. The anodes, of Acheson graphite, are suspended from the top and are enclosed by the steel plates which form the compartment for receiving the brine solution or electrolyte. With a few fittings such as the copper conductors, the automatic brine feed floats, the gage glasses for determining the height of the brine in the cell, and the chlorine outlet from the top of the cell, the cell is complete. The top is solid except for the openings for the anode, float and the chlorine outlet, which are sealed tight against leakage of gas.

Are there any expensive parts to the cell? No.

The top is a concrete casting of small dimensions, and will last five years or longer. It is subject to no stress because it is not restrained in any direction. It can be readily replaced at very small cost.

The cathodes are sheets of corrugated steel which last not less than five years. They are inexpensive.

The anodes are the most expensive but weigh only about 85 lb. for the above type. They last two years without replacement. The material is of the cheapest form. Cylinders $1\frac{3}{4}$ in. to 2 in. diameter and 2 ft. long, and a post rectangular in shape and approximately $2\frac{1}{2}$ ft. long, all pinned together with graphite pins.

The fittings are glass, rubber, and lead; all standard commercial forms and cheap.

There are no expensive metals or other materials involved. The machinist's work is limited to the work of pinning the graphite together, and this is furnished to the user at a minumum cost, due to the special machine tools which does the work quickly and cheaply because of the quantity production.

Discussion.

Mr. Frank W. Green.* I might say, as one of the operators of a plant where we generate our chlorine in this way, that although we have a very poor cell, and this cell of Mr. Marsh's seems to be a very great improvement upon our cell, we reported to the State Board of Health the cost of $1\frac{1}{2}$c. for home-made chlorine and $8\frac{1}{2}$c. for liquid chlorine purchased on contract. But that does not include the cost of the electric current. Most of the time we are running on water power, and figure the current does not cost us anything, and therefore we do not lay a charge for that. I

* Superintendent of Filtration, Montclair, N. J., Water Company.

think Mr. Marsh's figures are very conservative. That is to say, there would probably be more of a saving with a cell of that sort over liquid chlorine than he claims; for instance, our salt costs less than $10 a ton delivered.

I know of any number of men who have had to go to the hospitals due to chlorine poisoning on account of the valves of liquid chlorine tanks getting away from them. Now they have a better valve than formerly, and there may not be quite as much danger. But where you have a substance like chlorine under a high pressure there is always some danger, and men are apt to be careless after they get familiar with a thing of that sort, and we always have more or less potential danger.

Of course, in the case of generating it at the point of application, the chlorine is always under a slight suction. Then on the dosage; — where an electro-chemical engineer makes chlorine he figures entirely from an electrical standpoint; but I might say for the benefit of the chemists, that as the chlorine is absorbed by water, going in to the supply as a solution of chlorine, the amount of chlorine can be very readily checked up by taking the volume and the strength of the solution. In this way one gets a chemical check and it works out very nicely.

I know of four water plants that manufacture their chlorine at the present time, and all of them, so far as I know, are very well satisfied. They all continue to make it and find a saving in every way. At Trenton the cells are in a room with the rest of their apparatus, and there is no odor, no dirt, nor any other objectionable feature. I think that at most of the plants the cells and apparatus are examined every hour, but every well-managed plant would do that when using liquid chlorine. There should be an inspection of any apparatus of that sort at least once an hour, no matter how automatic it is supposed to be.

Another point: I noticed that with these tall brine tanks, as shown, Mr. Marsh says it is possible to settle out all the impurities. I think that the four plants in operation all filter their brine. They find it is quicker, and we are used to filtering, so that we just filter.

Another feature for the small plants which it might be well to bring out is that in all the cells that exist at present — I mean, the former cells — they insist on continuous service. I do not know how Mr. Marsh's cell is in that respect, and I think it is quite important if you can discontinue and use at will.

With the old cell — we use a Nelson cell — our greatest difficulty is graphite sludge forming in the bottom and stopping the circulation. Also in the "sulphating" of the connections between the bus bar and the individual rods that go to the several square carbons.

I have asked our foreman a number of times if he would rather manufacture chlorine or use liquid chlorine, and which he thought was the better, and he is very strongly in favor of our generating our own chlorine. He likes it much better than the use of liquid chlorine.

MR. MARSH. All cells are alike if you treat them right. The main essential is to purify your brine and filter or settle it. Ordinarily, water-works engineers know what to do when they want to settle out stuff. Filtering is a thing the chemist is versed in.

MR. GREEN. The brine filter is a very crude apparatus. Just run it through about a foot of sand. We find there is considerable dirt in the salt.

MR. MARSH. A better thing would be a plate filter, or filter press. That is what they use in the large chlorine plants.

In regard to the continuity of service, there is one thing I want to point out. In the large manufacturing plants they have a certain amount of equipment that they want to keep busy all the time. They have a certain number of cells, and in order to make money you have to keep your equipment running at normal capacity. If it runs under or above, it is poor manufacturing. On the other hand, to produce chlorine as you want it, this cell has been made for that purpose. It has such a low voltage that you can vary your current within wide limits and get your chlorine in the amount wanted. In our case it does not make so much difference, because you can't control the amount of liquid chlorine within 5 per cent. anyway, so that you are well within the limit if you produce 5 per cent. excess. Our position in water works is entirely different from a big manufacturing plant.

What was the other question?

MR. GREEN. In the continuity of service you mentioned, the number of water plants that run only twelve to fifteen hours a day.

MR. MARSH. It is undesirable to shut down the cells. I mean, it would be much better to absorb the chlorine in lime water and keep the cell running. But as a rule I have found in water-works service, you want to vary the amount of dosage, and keep a continuous flow. If you want 3 lb. of chlorine, you turn your ampere meter corresponding to 3 lb. Your efficiency varies a little bit, but within 5 per cent.

In regard to the sulphating at the connection, there are ways to overcome this which I will be glad to show you. Almost every big plant has a different method, and it is merely a matter of conforming to certain well-known facts. There is no secrecy about it.

MR. WELLINGTON DONALDSON.* May I ask Mr. Green how he charges up his power? He gets a surprisingly low figure.

MR. GREEN. Well, I did not consider power, because it is all generated by water power.

MR. DONALDSON. That is, you did charge it in the cost of a cent and a half a pound?

MR. GREEN. Oh, no. The electricity costs 2c. to 4c. a pound.

MR. MARSH. The power cost on these cells with direct current will vary from 1 kw.-hr. per pound of chlorine up. If you want to double the rate of chlorine you go up to $1\frac{1}{3}$ or $1\frac{1}{2}$ kw.-hr., direct current.

---

* Sanitary Engineer, American Water Works and Electric Company, New York.

You multiply your kilowatt-hour rate by 1, $1\frac{1}{3}$ or $1\frac{1}{2}$, plus the conversion cost from A.C. to D.C. But, as I say, approximately $1\frac{1}{4}$ kw.-hr. times your kilowatt-hour rate would be the cost per pound of chlorine at normal capacity.

MR. E. S. CHASE.* This paper of Mr. Marsh's is very interesting and recalls various earlier attempts to produce chlorine by electrolytic methods for use at the point of disinfection. If I recall correctly, there were at least two instances in New York State where electrolytic chlorine was used; one at Brewster, N. Y., for sewage disinfection, and another at Utica, N. Y., for water disinfection.

In connection with the estimated cost of chlorination by means of hypochlorite installations and with liquid chlorine apparatus, it would seem desirable to secure actual costs from plants in operation. The compilation of such costs would be well worth while.

In Mr. Marsh's estimate he figures the depreciation of the chlorine cylinders as a part of the cost upon the consumer, but it is my understanding that such depreciation falls upon the manufacturers of the chlorine rather than directly upon their customers.

Properly designed bleach plants, for example one at New Rochelle, N. Y., have not been found particularly difficult or inconvenient to operate. In fact, it does not appear on the face of it that apparatus for the control and application of chlorine solution prepared from chlorine generated at the water-works plant would be any less difficult to handle and control than bleach solution as ordinarily prepared.

Relative to handling liquid chlorine cylinders, the labor is comparatively small. Furthermore, the space required for storage of considerable quantities of chlorine in liquid form is not large, as contrasted with the storage required for salt bought in carload lots, from which chlorine would be generated electrically.

It would appear to me that the apparatus for applying the chlorine solution made with chlorine produced electrolytically would not be materially simpler than the ordinary solution tanks and constant level orifice boxes used with bleach apparatus. Furthermore, were movable electrolytic cells used it would seem that the problem of conveying the gas to the point of application would be somewhat complicated.

While there is no question that such apparatus could be properly cared for, as Mr. Marsh suggests, in the laboratory or where machinery is located which must be inspected, this same advantage holds true with liquid chlorine apparatus. On the other hand, many chlorination plants are located in isolated spots where inspection is relatively infrequent.

The automatic electrical control of the production of chlorine appears to offer some advantages, but just how this would be applied is not clear from Mr. Marsh's paper, — presumably from the use of a Venturi meter on the water main. A question which I would like to ask Mr. Marsh is

* Sanitary Engineer, with Metcalf & Eddy, Boston.

whether the evolution of chlorine from the brine takes place at the same rate with a freshly charged cell as with a cell containing brine from which the chlorine has largely been liberated, assuming the same amount of electricity passing through the cell?

In connection with the electrolytic cell it must be noted that continuous electric current is apparently essential. Consequently, on services where interruptions are liable to occur there would appear to be considerable opportunity for interruption in the chlorination process and danger of untreated water being delivered to the municipality.

Another question which arises is as to how the ordinary attendant available at a water-works plant, not employing a chemist, would know when his electrolytic cell would have to be provided with fresh brine. Is there not, therefore, the possible danger cf the brine having its available chlorine exhausted without the water-works operator being aware of the condition?

On the whole, it would appear that the electrolytic production of chlorine for the disinfection of water and sewage might well prove advantageous in the case of the larger installations where the quantities of water or sewage to be treated are large, where adequate storage facilities are provided and proper expert supervision maintained. It would appear to the writer that in case of the majority of the smaller water works where chlorination is the sole method of purification, the complications of the process would render it decidedly difficult to utilize with any assurance of proper disinfection of the water.

Mr. Marsh. Chlorine gas is withdrawn from the electrolytic cell batteries under suction by a water ejector and delivered to the main body of water direct.

There is no apparatus needed for the control and application of a chlorine solution other than a water ejector.

A water ejector is all that is needed to apply the chlorine to the water.

The chlorine is made proportionately to the electric current passing through the cells. The electric current is controlled by hand or automatically.

The chlorine is therefore delivered to the ejector and the water without the need of such things as solution tanks, etc.

The chlorinated water from the ejector passes through a rubber hose to the point of application, in the same manner as practiced in using chlorine gas from liquid chlorine.

Either apparatus can be located in a laboratory or in a separate building. It is only a question of hazard under unusual conditions such as leaks or fire.

Chlorine stored under high pressure is more hazardous than chlorine generated under suction and which requires no storage of chlorine. Throwing an electric switch will stop the electric current and stop making chlorine. This is a simple and effective procedure.

Both methods need occasional inspection wherever located.

Chlorine is constantly generated at a fixed rate when the amperes or electric current is fixed. The difference in a new and old cell is about 5 per cent. This is allowed for by slightly increasing the amperes in an old cell.

The brine is constantly fed to the cell, and there is no difference in the quality or amount of brine in a new or old cell.

If electric current is interrupted, sodium hypochlorite can be made from the chlorine and caustic soda liquor from the cell and held as a solution for emergencies. This solution can be applied to the water through the water ejector during the interruption of electric current.

Or steam generated or oil and gasoline generated electric-power apparatus can be held in reserve for emergencies instead of reserve transformer apparatus.

Or liquid chlorine and bleach can be held in reserve.

Fresh brine is being constantly fed to the cell and held at a predetermined level by feed floats. A chemist is not needed. The attendant simply observes if the brine level is all right.

The electrolytic generation of chlorine is like other things not yet in universal use. Oftentimes we imagine a thing is complicated if we know little about it. General use removes this error.

POLLUTION OF STREAMS AFFECTING INDUSTRIAL USES.

BY J. FREDERICK JACKSON.*

[*Read September 16, 1921.*]

The uses of water in a manufacturing state like Connecticut are varied, but in general divide into two broad classes, — potable and industrial.

The classes merge in some cases where plants use the municipal supply for both drinking and manufacturing. The effect of stream pollution on either is of considerable importance. Plants using large volumes of water in the processes of manufacturing take most of it from rivers where its quality is satisfactory. Where it is not, they are forced either to use the city supply, to obtain water from underground sources, or seek a distant supply on some unpolluted stream. Some plants for economic reasons prefer to take river water as it is and treat it for use in their particular process. The additional expense thus entailed is often a considerable item in fixing the price of the manufactured article.

In general, once a stream becomes grossly polluted by domestic or industrial wastes, it is eliminated as a source of potable supply. No attempt is made in this state to use grossly polluted rivers for drinking purposes, so that stream pollution as affecting this use of water can be disregarded in this discussion. Exceptions are the use in cases of emergency, such as that of the Connecticut River by Hartford in the drought of 1900 and where dual connections are permitted for fire protection. The cost of treatment in the one, and constant and close supervision in the other, required to protect public health, makes the pollution in these cases serious. Even if the rivers were clean, under present conditions they would be used for these purposes only in an emergency.

Industries using Water.

The industries using the largest volumes of water are the copper and brass, iron and steel, the rubber, the textile, paper and the silk. It is difficult to state the volume used in each trade, because in many plants no record is kept and estimates vary widely. On some streams the entire flow of a river is diverted through the plant at certain seasons of the year. Some idea may be had from the following estimates of the volume of water used by all industries on the Naugatuck and Hockanum rivers:

Waste Waters from Factories.

	Gal. per Day.
Naugatuck River	73 082 000
Hockanum River	8 000 000

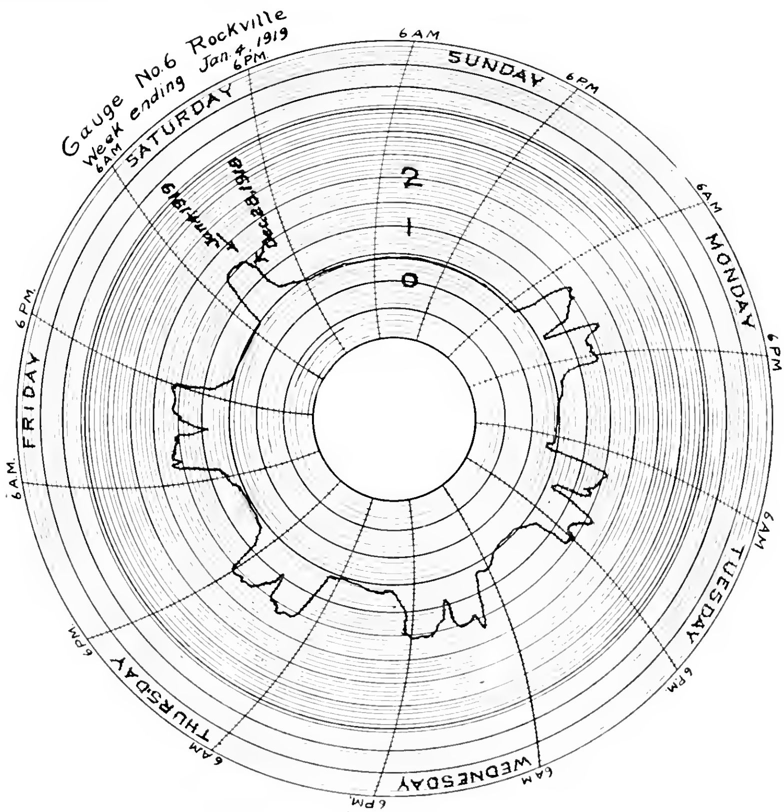
* Director, Bureau of Sanitary Engineering, Connecticut Department of Health.

WATER CONSUMPTION.

	Gal. per Day.
Naugatuck River	21 050 000
Hockanum River	1 740 000

The relation between the use for domestic and industrial purposes is shown clearly by these figures, and even more so if we consider two specific cases.

The estimated water consumption of Torrington is 2 710 000 gal. per day. The plant of the Coe Brass Company in this city used from its own private supply 8 150 000 gal. per day.



Variation in flow Hockanum River.

The estimated water consumption for Waterbury is 11 600 000 gal. per day. The Scovill Manufacturing Company from its private supply used 13 950 000 gal. per day.

In this connection the record of gage heights of the Hockanum River below the city of Rockville is very interesting.

By comparing flow for week days and Sundays, it appears that twelve factories use practically the entire flow of the river in their processes of manufacture.

Evidently, then, one of the main considerations determining the location of industries on our rivers was volume of flow. The constancy of this volume is another very important factor, but we do not propose to discuss that here.

The second main consideration affecting the use of water industrially is quality.

The quality of water desirable for boiler purposes has been the subject of much discussion, and the amount and character of chemical constituents permissible have been quite definitely determined. Obviously it is of much importance in industrial use, but it is unnecessary to discuss it in detail here, other than to call attention to the undesirability of attempting to apply standards determined for one section of the country to others where the geology, topography, and physical and chemical constituents of the water are markedly different.

Use and Quality of Water in Different Industries.

Copper and Brass.

In this industry large volumes of water are used in separating the particles of copper and brass from the dirt and other mineral matter in the ash from melting furnaces, for cooling the rolls, and in the pickling and rinsing processes.

Sulphuric acid and soda ash, sodium bichromate, sodium cyanide, nitric and hydrochloric acid are used in the pickling and rinsing operation, and any excessive amounts of mineral constituents would undoubtedly affect these.

If free acid were present in the river water, machinery and piping would be attacked.

Iron and Steel.

The use of water in this industry is somewhat similar to that in the brass and in cleansing articles from rust and oil, in rinsing after pickling and rinsing after plating. Soda and caustic soda are used in the cleaning process, sulphuric acid in the pickling, and cyanide in the plating.

Rubber.

In the manufacture of articles from crude rubber, the use of water is principally in the softening process and on the rolls.

In the regeneration of rubber large volumes of water are used in the process of devulcanization. Some sulphuric and hydrochloric acid are used and a considerable amount of alkali.

The industries in the Naugatuck Valley are for the most part more concerned with the effect of the river water on the efficiency and life of their boilers than its effect on manufactured articles. In general, they feel that any water that would be suitable for steaming purposes in a power

plant would be satisfactory for general industrial use. It is recognized, however, that pollution by decayed animal or vegetable matter, acids and excessive amounts of lime and magnesia are undesirable, and in any cleansing operation, freedom from color, odor, suspended matter, microscopic organisms, and fecal bacteria is desirable.

Woolen Industry.

The use of water in this industry is for scouring and rinsing the raw wool, dyeing, carbonizing and fulling. Soda ash and soap are used in the scouring, various dyes in the dyeing, sulphuric acid in the carbonizing, and soda ash in the fulling and milling.

A water free from suspended matter, free acid and peaty acids and iron, not too high in color and with limiting amounts of calcium, magnesia, sulphates and chlorides and organic matter, even though non-fecal, is required.

Paper.

In the paper industry large volumes of water are used in boiling of rags, in washing the rag and paper pulp, in bleaching, in cooling rolls of machines, in the moistening process and in the presses. A water similar to that required in the woolen industry is necessary, though in the manufacture of strawboard or rougher grades of paper the limiting amounts may be much greater than where finer grades are made.

Bleaching and Dyeing.

Bleaching and dyeing are generally closely associated with woolen, paper and silk industries; and where this is so, constituents affecting color or hardness and polluting organic matter are detrimental, and iron, even in traces, is very serious in the dye baths.

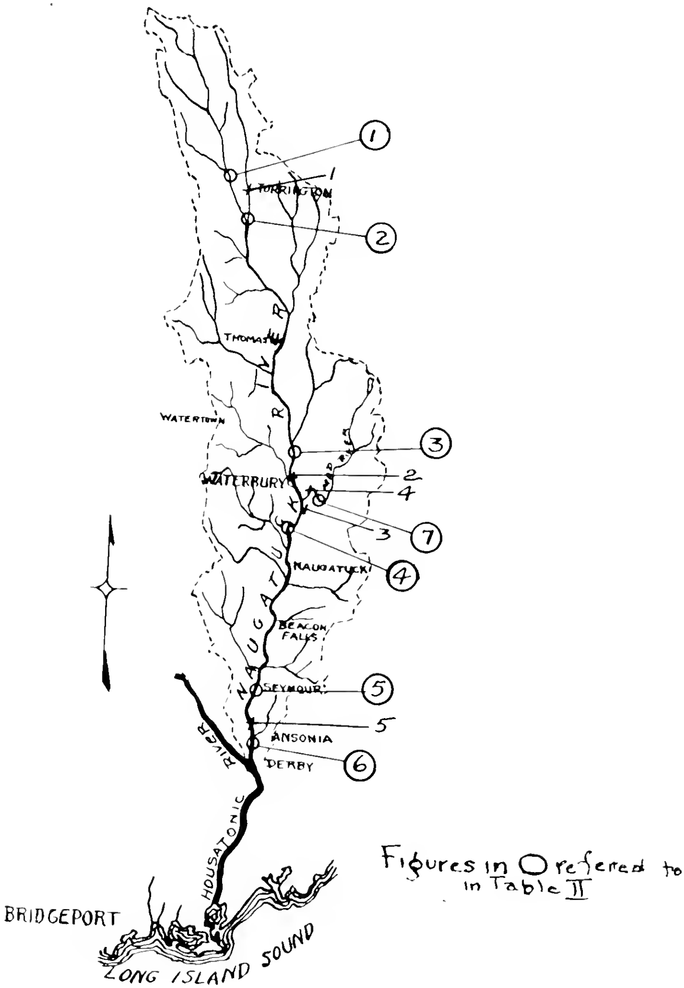
Silk.

In this industry large volumes of water are used in washing and boiling cocoons and frissons, in the sizing, and the dye houses. Two principal factors are hardness and color. Except for special purposes such as boiling off the silk and dyeing very light shades, where the hardness and color must be reduced to zero, 15 to 30 p.p.m. hardness and 10 to 25 p.p.m. color are permissible, any organic impurities and the faintest trace of iron is detrimental.

The quality of a water is determined by the amount and nature of polluting materials it may contain. These substances are those naturally inherent in the water, which it has taken by contact and holds in a dissolved or suspended state, and the added impurities due to the discharge into them of domestic and industrial wastes.

To determine the degree of pollution, it is necessary to know the amount and character of the suspended wastes, the dissolved matter — both mineral and organic — microscopic organisms and bacteria. For the use of water by industries we are mostly interested in the mineral content,

though in some cases the organic nitrogen and bacteria may have a serious effect upon the manufactured product. Complete mineral analyses of the rivers of the state are very few, and where taken have generally been of separate samples, and not of samples collected over any extended period. In our work, we took full sanitary analyses of the Naugatuck and Hocka-



NAUGATUCK RIVER
MAP OF WATERSHED

num rivers over a considerable period; and on the Naugatuck we have from records of factories full mineral analyses for similar points on the river, though taken at an earlier date. The results of these analyses are given in the following tables.

Number 1 in Table 1 is of the Naugatuck River at Torrington, before its use by the factories.

Number 2, after the river has received the wastes of Torrington, Thomaston, and Waterville, and has undergone whatever self-purification takes place before its use at Waterbury.

Number 3 is from the river at Waterbury, a little lower down.

Number 4 is from the Mad River, which enters the Naugatuck near where Number 3 was taken.

Number 5 is from the river above Ansonia and before its use by the factories of that city.

Number 6 is from the municipal supply at Ansonia and is introduced for purpose of comparison.

The analyses were taken monthly, May 1912, to May 1913, with the exception of the month of December.

The analyses in Table 2 are for the period June 1918, to June 1919.

Number 1 is from the river above Torrington.

Number 2, below Torrington.

Number 3, above Waterbury.

Number 4, at Waterbury, below the Mad River.

Number 5, above Ansonia.

Number 6, below Ansonia.

Number 7, the Mad River.

Table 3 gives analyses of wastes from copper and brass, the rubber, the iron and steel, the woolen, paper and silk industries.

Assuming that the samples above Torrington show the condition of the river with the natural impurities inherent to it, the effect of the discharge of industrial wastes should appear in the analyses lower down on the river.

The chemicals used in Torrington factories are acids, principally sulphuric, muriatic, and nitric, 1 242 000 lb.

Alkalies, mostly caustic soda and potash and sodium carbonate, 128 000 lb.; metal salts, principally sodium cyanide and bisulphite, zinc, nickel, and copper, 42 000 lb.; miscellaneous, 122 000 lb.

At Thomaston, acids 250 000 lb., alkalies 7 800 lb., metal salts, 1 400 lb., miscellaneous, principally soap, 24 000 lb. This makes a total

Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
1 492 000 lb.	135 800 lb.	43 400 lb.	146 000 lb.

Comparing analyses, above Torrington in Table 1 with that above Waterbury, there is a slight increase in copper, silica, iron and aluminum oxides, lime, and soda; no increase in magnesia; the hardness is unchanged; a decrease occurs in free acid; a large increase, which would naturally be expected, in total sulphuric; chlorine increased and free alkalies decreased. Evidently considerable self-purification takes place between Torrington

TABLE 1.

Number. Location of Sample.	Copper	Silica. SiO_2.	Iron and Alumina Oxides. $Fe_2O_3+Al_2O_3$.	Lime. CaO.	Magnesia. MgO.	Soda.	Total Solids.	Fixed Solids.	Volatile Solids.	Temporary Hardness.	Permanent Hardness.	Free Acids. H_2SO_4.	Total Sulphuric Acid. SO_3.	Chlorine.	Free Alkali.
No. 1. Maximum	0.0	16.3	12.6	11.3	5.6	11.5	109.9	58.4	54.6	5.4	24.9	20.0	8.4	6.0	9.2
Minimum	0.0	0.6	0.8	5.4	2.6	4.9	42.0	20.9	19.0	1.1	13.2	0.0	2.8	0.9	2.9
Mean	0.0	4.9	5.9	8.5	3.6	7.7	73.2	37.3	36.0	3.0	20.5	5.1	4.8	2.9	5.2
No. 2. Maximum	0.6	20.7	15.0	15.3	8.4	21.3	123.2	80.7	48.3	5.3	33.2	7.9	27.2	8.0	4.8
Minimum	0.0	0.9	3.1	4.6	1.6	4.8	46.7	24.4	19.3	0.7	11.6	0.0	5.8	1.2	0.0
Mean	0.08	6.9	6.8	9.4	3.6	9.9	81.2	47.8	33.4	2.9	20.4	3.2	12.0	4.1	2.4
No. 3. Maximum	1.2	42.9	44.5	19.1	6.3	35.0	219.7	168.9	83.8	11.4	47.4	9.6	70.4	19.3	0.8
Minimum	0.0	1.9	6.4	6.3	2.5	6.4	54.4	32.6	19.0	0.0	12.4	1.4	7.1	2.5	0.0
Mean	0.25	8.0	20.9	10.9	4.2	14.2	128.4	80.9	47.5	3.4	23.8	4.5	24.4	7.6	0.26
No. 4. Maximum	7.8	16.9	25.2	10.3	6.5	55.2	357.9	335.0	69.4	7.8	98.9	28.8	102.8	11.9	2.0
Minimum	0.0	2.1	4.4	4.1	2.0	7.1	80.1	45.8	22.9	0.9	13.2	2.6	12.4	0.7	0.0
Mean	2.18	9.4	10.9	7.3	3.1	24.9	151.0	109.3	41.6	4.3	42.7	11.5	45.8	6.3	0.66
No. 5. Maximum	1.4	12.4	12.8	23.3	6.2	33.5	172.8	137.2	60.4	7.4	42.8	38.8	56.0	14.0	3.2
Minimum	0.0	2.0	3.2	6.1	1.4	6.9	58.0	34.8	20.5	0.8	14.5	0.0	7.5	2.0	0.0
Mean	0.51	6.9	6.9	12.7	3.5	15.5	107.6	72.0	35.6	3.6	24.5	9.7	22.1	7.8	1.6
No. 6. Maximum	0.0	6.7	12.3	11.8	3.0	8.1	73.0	48.8	33.8	3.9	18.8	11.6	6.4	56.0	2.4
Minimum	0.0	1.4	0.7	3.8	0.7	3.8	32.8	10.8	11.4	0.1	9.2	0.0	2.0	7.5	1.2
Mean	0.0	3.3	4.4	5.5	1.7	15.6	45.8	24.8	21.0	1.6	12.6	3.9	4.1	22.1	1.7

TABLE 2.

Number Location of Sample.	Free Ammonia.	Organic Nitrogen.	Oxygen Consumed.	Total Solids.	Total Suspended Solids.	Chlorine.	Alkalinity.
No. 1. Maximum	0.28	0.78	9.4	105	5	7.2	31
Minimum	0.05	0.21	6.6	42	2	2.4	14
Mean	0.12	0.51	8.2	74	4	4.7	23
No. 2. Maximum	1.72	3.87	14.0	282	91	11.7	35
Minimum	0.18	1.01	10.5	77	22	1.0	17
Mean	0.89	2.23	12.4	149	43	8.8	26
No. 3. Maximum	0.42	1.09	8.5	134	12	10.2	23
Minimum	0.08	0.19	5.2	39	3	4.4	10
Mean	0.18	0.59	6.2	80	7	6.3	16
No. 4. Maximum	1.93	3.12	14.3	309	37	14.2	17
Minimum	0.24	1.06	6.8	83	14	4.6	5
Mean	0.86	1.87	10.2	175	24	10.8	12
No. 5. Maximum	1.78	1.87	8.6	285	19	17.4	25
Minimum	0.18	0.78	7.1	77	9	5.2	10
Mean	0.89	1.25	7.9	147	12	10.2	16
No. 6. Maximum	2.49	1.90	9.2	237	16	17.3	28
Minimum	0.73	0.22	7.0	78	8	4.8	9
Mean	1.50	0.94	7.8	158	12	10.3	17
							+ −
No. 7. Maximum	1.09	2.35	17.2	243	57	16.5	17 23
Minimum	0.31	1.47	12.3	112	18	7.6	14 3
Mean	0.65	1.89	14.3	174	31	11.3	Av. −6

TABLE 3.

	Free Ammonia.	Organic Nitrogen	Oxygen Consumed.	Solids. Total.	Solids. Volatile.	Solids. Suspended. Total.	Solids. Suspended. Volatile.
Copper.							
Maximum	4.48	6.99	184.0	2 583	916	232	95
Minimum	0.05	0.22	3.1	138	28	11	1
Mean	...	1.74	24.0	803	295	51	26
Maximum	9.60	6.30	44.4	502	222	139	111
Minimum	0.08	0.91	3.9	185	37	26	20
Mean	2.27	2.35	20.3	316	102	68	49
Maximum	1.04	3.84	32.0	29 860	625	29 530	516
Minimum	0.11	0.43	17.1	905	153	630	58
Mean	0.36	2.93	23.4	7 621	335	11 093	258
Iron and Steel.							
Maximum	1.00	68.0	3 750	71 000	47 960	67 000	6 405
Minimum	0.34	0.2	82	1 050	255	160	80
Mean	0.67	17.8	890	25 510	11 309	15 236	2 729
Maximum	3.52	1.76	315	44 100	32 380	850	240
Minimum	0.52	0.08	7	550	270	0	0
Mean	1.33	0.75	85	11 356	7 862	266	72
Maximum	1.60	0.99	86	819	500	500	120
Minimum	0.08	0.20	3	140	30	0	0
Mean	0.56	0.69	25	416	138	133	27
Rubber.							
Maximum	4.32	23.52	570	1 625	999	1 395	960
Minimum	0.96	3.84	41	298	165	70	48
Mean	2.56	5.60	80	419	285	185	127
Maximum	7.2	43.5	870	7 105	6 010	5 792	5 772
Minimum	3.6	2.7	46	433	230	122	89
Mean	5.4	17.9	305	2 728	2 183	2 145	2 118
Maximum	16.8	75.5	3 100	14 091	5 945	602	386
Minimum	11.2	47.5	1 160	8 484	3 175	212	148
Mean	13.4	66.5	2 132	11 392	4 279	378	271
Woolen.							
Maximum	80.0	30.4	1 900	5 840	1 630	1 280	785
Minimum	0.08	1.2	49	217	144	50	40
Mean	14.5	11.1	822	2 554	1 264	408	324
Silk.							
Mean	2.32	590	3 220	36 800	14 400	8 400	7 000
Paper.							
Maximum	2.2	14.8	421	5 400	2 720	730	539
Minimum	0.08	0.09	20	260	90	110	73
Mean	0.49	4.80	153	1 047	591	324	226

TABLE 3. — *Continued.*

	Chlorine.	Alkalinity. $CaCO_3$.	Iron.	Copper.	Sulphates. SO_4.	Dissolved Oxygen Demand.	Remarks.
Copper.							
Maximum..	86.5	28	...	555	1 358	...	Pickle and Dip Rinse Waters.
Minimum...	3.0	−715	...	3	36.8	...	
Mean......	20.2	−161	...	54.6	373	...	
Maximum..	26.0	87	...	5.6	110	...	Plating Rinse Waters.
Minimum...	3.5	23	...	0.4	33	...	
Mean......	15.1	56	...	2.3	67	...	
Maximum..	133	290	...	332	...	...	Tailings.
Minimum...	22.5	22	...	12	...	...	
Mean......	78.7	124	...	109	...	...	
Iron and Steel							
Maximum..	5 000	33 000	1 300	...	...	...	Cleansing Rinse Waters.
Minimum...	140	120	1.2	...	...	...	
Mean......	1 803	7 814	275.4	...	...	...	
Maximum..	1 250	−70	520	...	5 460	...	Pickle and Dip Rinse Waters.
Minimum...	8	−20 500	4	...	175	...	
Mean......	395	− 4 163	212	...	2 349	...	
Maximum..	120	128	6.4	...	...	...	Plating Rinse Waters.
Minimum...	40	−70	0.0	...	...	...	
Mean......	68	25	2.9	...	...	...	
Rubber.							
Maximum..	28.0	100	...	...	...	115	Crude Rubber Washings.
Minimum...	4.5	16	...	...	...	10	
Mean......	14.5	38	...	...	...	20	
Maximum..	170	−60	...	...	...	3 745	Acid Room Waters.
Minimum...	5	−3 100	...	...	...	342	
Mean......	75	−998	...	...	...	2 043	
Maximum..	149	2 510	...	...	...	1 926	Tank Effluent.
Minimum...	28	−575	...	...	...	1 653	
Mean......	82	814	...	...	...	1 790	
Woolen.							
Maximum..	150	3 200	...	...	...	...	
Minimum...	3	60	...	...	...	...	
Mean......	51	1 003	...	...	...	...	
Silk.							Concentrated Composit Sample.
Mean......	...	...	...	...	...	...	
Paper.							
Maximum..	108	390	...	...	...	...	
Minimum...	5	12	...	...	...	...	
Mean......	36	82	...	...	...	...	

and Waterbury, and this is confirmed in Table 2. In the analyses below Torrington there was a decided increase in all the determinations except alkalinity, while in the analyses above Waterbury there was a very noticeable decrease.

The amounts of chemicals used, pounds per annum, in Waterbury, including Waterville and Watertown, were —

Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
8 693 507 lb.	1 185 982 lb.	2 316 015 lb.	10 921 785 lb.

The analyses in Table 1 show a decided increase in the copper, iron and aluminum oxides and soda. Total and mineral solids, total sulphuric acid, and the chlorine, silica, lime, magnesia, hardness and free acid were slightly increased, and free alkalies showed a decided decrease. In Table 2 all determinations were noticeably increased except the alkalinity.

The amounts of chemicals used in pounds per annum at Naugatuck, Beacon Falls, and Seymour were —

Acids.	*Alkalies.*	*Metal Satts.*	*Miscellaneous.*
7 374 000 lb.	1 184 000 lb.	243 000 lb.	12 213 000 lb.

The analyses of the river above Ansonia compared with those below Waterbury show marked decrease in all constitutents except the soda and free alkalies, which show an increase. In Table 2 all determinations are decreased except free ammonia and alkalinity. Self-purification has again evidently taken place.

In this connection it is interesting to compare analyses of the Mad River with analyses of the Naugatuck above and below its entrance. In Table 1 the copper, soda, total and mineral solids, hardness, free acid, total sulphuric acid and chlorine were considerably above those in the Naugatuck, the silica only slightly and the iron and aluminum oxides, lime, and magnesia considerably less. The large increase in free alkalies is particularly noticeable, and no explanation suggests itself. In Table 2 the analyses of the Naugatuck below the entrance of the Mad River show an increase in the free ammonia, organic nitrogen, and total solids; a decrease in oxygen consumed, suspended solids and chlorine and a marked change from acidity to alkalinity. The beginning of the absorption of the heavy pollution of the Mad River by the Naugatuck is noticeable from these results, and this action apparently continues in spite of the added pollution lower down.

The amounts of chemicals in pounds per annum used at Ansonia were

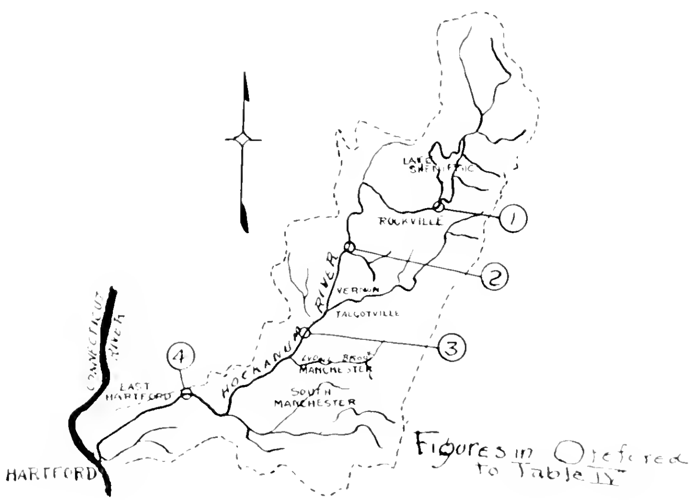
Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
1 945 101 lb.	21 123 lb.	25 062 lb.	627 270 lb.

Full mineral analyses of the river below this city are not available, but the sanitary analyses when compared with that above the city show an increase in the free ammonia and total solids, a decrease in the organic

nitrogen and slight changes in oxygen consumed, suspended solids, chlorine, and alkalinity.

Comparing analyses of the copper, iron, and steel and the rubber wastes with the river water, it is noticeable that while the free ammonia in waste waters from the rubber industry was as high as 16.8 p.p.m. and organic nitrogen 75.5 p.p.m., in the river below they were only 1.78 p.p.m. and 1.87 p.p.m. In the waste waters from the iron and steel, oxygen consumed ran as high as 3 750 p.p.m., total solids 71 000 p.p.m., chlorine 5 000 p.p.m., alkalinity 33 060, iron 1 360 p.p.m., acidity 20 500 p.p.m.; while in the river, taking them in the same order, the highest figures were 14.3 p.p.m., 309 p.p.m., 14.2 p.p.m., and 17 p.p.m. Even in the Mad River the acidity never exceeded 23 p.p.m.

The explanation for this would appear to be the effect of dilution when mixed with waters of the Naugatuck and the opportunity afforded for sedimentation by the numerous mill ponds.



HOCKANUM RIVER
MAP OF WATERSHED

Unfortunately, full mineral analyses of the Hockanum River are not available, but Table 4 gives results of sanitary analyses for the period from July 1918, to July 1919.

No. 1 is at Lake Schenipsit.

No. 2 is below Rockville.

No. 3 is above Manchester.

No. 4 is at Burnside, below the entrance of the South Branch, on which are located large silk mills and paper companies.

No. 5 is analyses of rain water, collected at the Yale Medical School, New Haven, during 1889–1890. The quality of water suitable for use in

the woolen and paper industries is often described as that akin to rain water, and this is introduced here for comparison with water from Lake Schenipsit, which is considered satisfactory.

TABLE 4.

	Free Ammonia.	Organic Nitrogen.	Oxygen Consumed.	Total Solids.	Chlorine.	Alkalinity.	Albuminoid Ammonia.	Nitrites.	Nitrates.
No. 1. Maximum..	0.19	0.82	6.6	92	7.0	15	...	...	...
Minimum..	0.00	0.22	1.2	23	1.5	9	...	...	...
Mean......	0.08	0.46	4.9	47	4.1	13	...	...	...
No. 2. Maximum..	1.68	2.82	26.0	207	16.5	55	...	...	...
Minimum..	0.29	0.38	5.8	56	5.0	21	...	...	...
Mean......	0.73	1.33	11.2	122	10.2	38	...	...	...
No. 3. Maximum..	0.37	2.06	9.7	89	6.5	28	...	...	...
Minimum..	0.02	0.56	3.4	54	4.0	18	...	...	...
Mean......	0.15	0.90	6.5	76	5.6	22	...	...	...
No. 4. Maximum..	1.09	1.81	13.0	170	14.5	47	...	...	...
Minimum..	0.04	0.32	5.0	56	5.0	17	...	...	...
Mean......	0.50	1.01	8.0	105	8.8	35	...	...	...
No. 5. Maximum..	5.20	...	...	47.4	4.6	..	0.142	0.010	0.16
Minimum..	0.34	...	...	18.0	0.7	..	0.050	0.001	0.02
Mean......	0.83	...	...	13.4	1.77	..	0.071	0.005	0.06

Obviously rain collected from an atmosphere laden with the gases and fumes from a manufacturing community is quite different from that collected where the air is free from such contamination. In these analyses the rain was collected monthly for fourteen months. The solids and nitrogenous matter are much larger that we would expect to find in a pure water.

The chemicals used in the factories at Rockville, in pounds per annum, are,—

Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
123 000 lb.	479 000 lb.	184 000 lb.	823 000 lb.

Acetic and sulphuric predominate in the acids, soda ash in the alkalies, compounds of sodium in the metal salts, and soap and dyestuffs in the

miscellaneous. All the determinations show a noticeable increase below Rockville.

The chemicals used in Manchester, in pounds per annum, are,—

Acids.	*Alkalies.*	*Metal Salts.*	*Miscellaneous.*
329 000 lb.	226 000 lb.	797 000 lb.	2 763 000 lb.

Sulphuric predominates in the acids, soda ash in the alkalies, iron in the metal salts, and soap and dyestuffs in the miscellaneous.

All the determinations, excepting organic nitrogen and oxygen consumed, show a decided increase in No. 4 over those in No. 3.

Comparing the analyses of the woolen, paper, and silk wastes with analyses of river water, the marked decrease in oxygen consumed, total solids, chlorine, and alkalinity is noticeable. This is partly accounted for by the passage of the woolen wastes at Rockville and the silk wastes at South Manchester through the sewage treatment plants and the sedimentation of paper wastes in lagoons on Lydall Brook and in Union Pond. The dilution by the flow of the Hockanum River undoubtedly effects some reduction.

Conclusions.

Stream pollution is a very important factor in the industrial use of water.

The volume of water used industrially is about three times that for domestic use.

For the industries discussed in this paper, it may be assumed that any water suitable for boiler feed purposes in one industry would be satisfactory for all. The opposite is true for other uses of water by the several industries.

In the brass and copper and iron and steel industry, a water suitable for boiler-feed purposes would probably be satisfactory for manufacturing uses. Excessive amounts of organic and suspended matter and free acid would be objectionable.

The water of the Naugatuck River can be used in its present condition in these industries.

In the manufacture of articles from crude rubber, presence of acids is undesirable; in cooling process, organic matter, if finely divided, is not objectionable.

In regeneration of rubber, condition of water has very little effect, and the condition of the Naugatuck River, as it is, is not considered objectionable.

The woolen industry requires a "soft" water; calcium and magnesium compounds are detrimental. They prevent a proper lather from the soap, and tend to form insoluble precipitates. The water from Lake Schenipsit has always been found satisfactory.

The paper industry requires a water free from acids, suspended matter, high color, iron, calcium and magnesium, and organic matter. A very soft water is sometimes detrimental. In the manufacture of the coarser grades, a small amount of suspended matter is allowable. The waters of Lydall Brook have been found satisfactory for the manufacture of leather board, while the waters of the Hockanum River at Burnside require treatment before use in the manufacture of tissue and waxed papers.

Excessive hardness and high color, organic and suspended matter and iron are detrimental to the silk industry. For about two thirds of the work, hardness of 30 p.p.m. and color of 25 p.p.m. is allowable. In some special processes these must be reduced to zero.

Bleaching and dyeing require a clear, soft water, as near akin to rain water as possible. Calcium and magnesium, and even a trace of iron, is undesirable.

The wastes from many industries using similar processes do not pollute a stream so as to prevent its use industrially by allied industries.

For example, one brass or copper, iron or steel, or rubber factory on the Hockanum River would affect very seriously all the industries lower down, but the woolen factory in Torrington apparently does not affect the use of the river, one way or the other, by the brass companies.

The absorption by the rivers of the high polluting constituents of the various wastes is materially affected by the volume of flow and the opportunity offered for sedimentation by treatment plants or in mill ponds.

Many factories were located on rivers before the effect of pollution was evident. Locations were determined more by the volume of flow and suitability of water for steaming purposes than for its effect on manufactured articles.

The removal of pollution would undoubtedly be beneficial in its effect on boiler efficiency in all the industries.

No intensive studies have been made of the effect of pollution on the chemicals used or on the manufactured articles.

It is known, however, that some chemicals used in the woolen, paper, silk, and bleaching and dyeing industries are seriously affected by free acids, high color, large amounts of suspended matter, appreciable amounts of iron and organic matter, fecal or non-fecal.

The copper and brass and iron and steel industries are affected only by suspended matter.

The rubber industry appears to be affected the least of any by pollution.

The efforts of most manufacturers have been directed towards savings effected in obtaining a water suitable for steaming purposes. Little, if any, attention has been given to reducing cost of production and increasing value of product by removal of stream pollution.

It is known that calcium and magnesium decompose equal amounts of many chemicals; that waters containing iron are liable to develop brown gelatinous growths that affect cleansing processes where soap or alkalies

are used; that the bleaching power of certain chemicals is affected by chlorine.

The study of waters suitable for steaming has demonstrated that a considerable saving can be accomplished either by care in selecting a satisfactory supply or by treating an unsatisfactory one. Stream pollution must cause waste. The large amounts of chemicals used in the Naugatuck and Hockanum valleys should warrant intensive study of the effect of pollution on chemicals used.

Entirely aside from the general benefit to public health and comfort, the removal of stream pollution would be beneficial and effect savings in the use of water for steaming and and other industrial purposes.

Acknowledgment for some of the information used in preparing this paper is due W. H. Bassett, of the American Brass Company; John Goss, of the Scovill Manufacturing Company; Walter M. Scott, of Cheney Brothers; Herbert J. Regan, of the James J. Regan Company; T. R. Appell, of the Warrenton Woolen Company; O. L. Johnson, of the Aspinook Company; N. G. Read, of the Burnside Mills; C. F. McCarthy, of the Goodyear Metallic Rubber Shoe Company, and E. A. Andersen, of the Rubber Regenerating Company.

Discussion.

Mr. Harrison P. Eddy.* Mr. President, Mr. Jackson very kindly placed in my hands a copy of this paper just before the meeting. I have not had time to consider it in detail. However, it is very evident that this extensive study has furnished much valuable data on an important subject.

In connection with the water consumption, on page 15, Mr. Jackson, I assume that the figures given in the second part of the table are consumption for domestic purposes.

Mr. Jackson. That is right.

Mr. Eddy. The thing which of course at once appeals to one studying this subject is the very large volume of industrial wastes and the very great quantity of waste materials which go into the streams with the water. It is remarkable that our rivers will assimilate and dispose of so much of this material without creating more objectionable conditions than appear to be the case, not only from this study but from others of a similar nature.

Mr. Stephen DeM. Gage.† In some of the western states, notably in Illinois, the state has taken upon itself to make studies of the waters of the state, not only of streams but also of the ground waters and the public water supplies, in relation to their uses for industrial purposes. It seems to me that this is a very important thing for the state to do. Our New England states have not done this as yet, but there is a demand for something of the kind.

* Of Metcalf & Eddy, Boston.

† Chemist and Sanitary Engineer, R. I. State Board of Health.

I suppose I get, on an average, four requests a month from industrial concerns for information of one kind or another about the quality, either of some of our rivers in Rhode Island or some of our public water supplies, in relation to their use for some specific industry. Of course our larger industries, particularly those using large volumes of water, are located on the larger streams, and their requirements are pretty well defined. But there are many small industries — that is, industries requiring relatively small amounts of water — in which the chemical and other characteristics of the water supply are very important. Many of our newer industries which are growing rapidly are based on chemical processes which may be affected by the characteristics of the water used. It seems to me that it should be the duty of the state to have full information of this kind available for the use of prospective manufacturers. If a new industry which is just being developed is to come into your state it may mean a great deal to the industrial life of your state in one way or another, and the state should be in a position to aid that industry in determining where it is best to locate.

This of course is an economic problem, not a public health problem, and our state laboratories have usually been developed along public health lines. But with a minimum expenditure of funds the work of our state laboratories and our sanitary water surveys could be extended so as to obtain a great deal of information which it seems to me might be of very great economic importance.

Mr. M. N. Baker.* I want to express appreciation of the studies that have been made in connection with this matter, and to voice the hope that such studies may be continued in Connecticut and elsewhere, as being of great value. The studies seem to be unique from the points of view that have been taken. Heretofore most stream pollution studies have been directed against pollution, and this seems to be a broader study, as it takes into account the water supplied to the industries and the whole range of important elements involved.

Mr. Eddy. The importance of an adequate supply of suitable water and practical means of disposing of wastes for industries has come to be a very important matter, particularly in communities devoted largely to manufacturing. This subject, which formerly was given comparatively little weight in the selection of industrial sites, is now often carefully considered before the establishment of an industry in any particular locality.

In many cases, however, it is difficult, or impossible, to predict what the future conditions will be. A water which is suitable to-day may be so altered in the future by the discharge of wastes from some new or enlarged industrial plant, that its usefulness will be seriously inpaired. An industry which is established with a view to the discharge of untreated wastes into a river may soon find itself embarrassed by the erection, further down

* Associate Editor, *Engineering News Record*, New York.

stream, of a new industrial plant which requires a better water than that flowing past its property. It then becomes necessary to treat the wastes of the upper plant and perhaps also to treat the water used by the lower industry. In some cases, such treatment imposes a serious financial burden, and in others it may be considered impracticable to so treat all of the wastes that the waters into which they are discharged may be suitable for use in certain industries.

In many cases, lower riparian manufacturers hesitate to resort to the courts to secure treatment of wastes discharged into the river above, even though the law appears to be clear that they are entitled to receive the water in its natural condition, subject only to reasonable use by upper riparian owners. Accordingly, considerable courtesy is often extended to upper manufacturers, although many such cases have been litigated.

The increase in manufacturing and the decrease in the number of available suitable sites for the establishment of industries using process waters is gradually leading to a demand for some regulation of the quality of our streams. It is highly desirable that rivers be maintained in proper condition, but to determine what is the *proper condition* is exceedingly difficult. In some cases it is probable that this should be determined by the uses made of the river by the public and by considerations of public comfort. In other cases, perhaps the requirements of all the riparian manufacturers should control, and in some localities the agricultural interests may predominate and require that the waters be maintained suitable for watering stock and for irrigation.

It seems certain that the same standard of purity cannot wisely be adopted for all rivers, and that each stream must be considered under its own peculiar environment and conditions.

The first logical step in all cases must be to ascertain the conditions and needs. This can be done by investigations similar to those which have been made in Connecticut, under Mr. Jackson's direction. The accumulation of such valuable data will greatly assist in the correct solution of this very intricate problem.

MANGANESE BRONZE FOR VALVE STEMS.

BY WILLIAM R. CONARD.*

[*Read September 14, 1921.*]

This paper is chiefly concerned with valves as used for water-works purposes, so that the type or quality of valve stems as used in valves for other purposes will not be mentioned here.

Early water valves or devices for shutting off the flow of water in pipe mostly had a shaft or stem for operating the gate made of wrought iron, and even up to comparatively recent times some water works have continued to use wrought iron. However, for a fairly long period the use of a brass or bronze stem has been the custom, because of its non-corroding qualities. The early substitutes for wrought iron were largely common brass; then, in order to get greater strength, bronzes were resorted to, the best of which was known as the "Government mix" of 88 parts copper, 10 parts tin, and 2 parts zinc, and even yet some of our water works and manufacturers are satisfied with this material for the valve stems. The next step in the use of an alloy metal for valve stems was the adoption by some users of "Tobin bronze" and its companion metal, "Naval bronze." Tobin bronze is a patented trade name for a rolled bronze; Naval bronze is also a trade name for practically the same metal. Both of these bronzes, because of being worked or rolled after being cast into ingots and rolled into billets, present a more uniform texture than the same mix in cast form, and considerably increased strength, particularly in the smaller diameters and where they can be used without cutting away too much of the outer skin or section, which is the part which has the greatest strength, for, when the inner section or core is cut into, the strength decreases quite rapidly, though this is true of practically all bronzes, though in some to a lesser degree. There are a number of water works which regularly specify for their valve stems one of the rolled bronzes. One of the drawbacks to their use is in the difficulty of getting a proper collar on the stem for valves of the inside screw type, which are largely the only ones used in water works.

At about the time some water works commenced to specify the rolled bronzed for valve stems, some of the makers commenced making part of their output of stems of manganese bronze, but with indifferent success, as the production of manganese bronze is a specialty in itself and requires that it be made with the knowledge and studies which have been given it by those who specialize in its production. It can be produced to give

* Inspecting Engineer, Burlington, N. J.

practically any combination of physical characteristics desired, such as free machining qualities with moderate tensile strength and yield point, or much higher tensile strength with a combination of either high ductility and low yield point or low ductility and high yield point.

Confining ourselves primarily to gate valves for water-works purpose we find that the valve is made up of such parts as — body, seat rings, dome or cover, gates, face rings, wedging mechanism, stem, stuffing box, stuffing-box follower or gland, stem nut, gears in the case of larger valves, packing and gaskets, bolts and nuts, and in the case of what are termed "rising stems" the "yoke" and its parts.

Of these thirteen or more parts, the most important one is the stem, for upon it depends the proper opening and closing of the gate or gates and the operation of the wedging mechanism, which in turn controls the flow of the water, and if the stem fails the rest of the mechanism is practically useless. This is also in part true of the other parts, yet unless there should be a complete failure of the body, the other parts with the stem intact might function in part.

The actual work that the stem performs is lifting the load or weight of the gates, and the wedging device, overcoming the friction of the gates against the seats and the wedges in starting to open with the gate closed; the friction caused by the pressure of the water in the pipe during the later part of the travel in closing; the friction of water seal or packing in the stuffing box, and the friction of the threads on the stem working through the stem nut. The stresses set up depend on the pressure of the water against the gates and are tension on the body of the stem, shear on the threads and collar, and torsion, to a greater or less degree, during the entire operations of opening and closing.

The tension coming as it does on the body of the stem, the controlling diameter or cross-sectional area is that at the bottom of the thread, the shear controls the area of metal of the total amount of metal engaged in the thread of the stem nut when operating, and of the collar operating in its recess between the top of the bonnet and the lower part of the stuffing box, and the torsion is largely on the cross-sectional area of the stem at the base of the threads. Therefore in determining the diameter of the stem the area at the base of the thread should control, and not the full diameter of the stem, and high factors of safety should be allowed to provide not only for these stresses but also for the human element, which always enters in a device of this kind, and which is not always operated by persons who appreciate the importance of the fact that a valve is a machine and not simply a mass of metal that can stand all sorts of abuse.

In years past the big advantage of controlling and obtaining flexibilty of a water system by a comprehensive system of valves did not seem to have as large a place in the planning and in the construction of our water systems as it has to-day. What valves there were, were probably not operated as frequently as at present, so that while they had their

valve failures they were not particularly numerous; while nowadays with the need for conservation, and the desire to be efficient, more frequent inspection causes the valves in our water works to be operated at shorter intervals, with the accompanying stresses as before described placed on the stems at shortening intervals.

When wrought iron was used for stems, and the valve operated at irregular and fairly long periods, being of a metal that probably had a breaking strength of around 40 000 lb. per square inch, not a great deal of difficulty was had. Then when brass came into use, having very much less strength than iron, it was soon discarded in favor of bronze of about the 88-10-2 type, which gave some additional strength and greater ductility, the ductility of valve stems having been thought at this period to be an important factor.

It is entirely true that if there were nothing but the tension and torsion stresses that need be considered, ductility would be of very great importance, but there are other conditions which often develop that make high ductility not only unnecessary but often dangerous.

For example, when the stresses on a valve stem become great enough to exceed the "elastic limit" of the metal, the stem commences to distort, either elongating, buckling, or twisting, and with the load removed the stem remains distorted because the limit of its elasticity has been passed. Now in bronze, while it is possible to produce it with a high "elastic limit or point of yield" and a high ultimate strength, the ductility is reduced; whereas to attain a high ductility while a fairly high ultimate strength may be retained the yield point drops to a comparatively low point; in other words, generally speaking, the yield point and elongation vary with each other inversely. This, then, brings us to the point where we must decide whether we desire a metal of high yield point and enough ductility so that we do not get a failure without warning and with, of course, a good high ultimate strength; or whether we will sacrifice the higher yield point and obtain a metal that will flow or yield extensively before breaking. After giving the matter extended study and consideration, I have come to the conclusion that the best bronze for valve stems is that which has the characteristics of high yield or elastic limit, moderate ductility, high ultimate strength, but not more than 100 per cent. higher than the yield point.

My reason for this conclusion is that immediately a stem is distorted by stressing it beyond the point of yield, whether it be stretched, buckled or bent, or the pitch of the thread upset, the valve is rendered practically useless until a new stem is put in, and if a metal can be obtained which because it has the virtue of a high elastic limit, thereby placing the likelihood of a distorted stem in the range of improbabilities, I feel that the valve is that much nearer being fool proof, and that the efficiency of the water-works system in which such valves go is thereby increased.

And the one good thing about all of this is that it is being done at practically no increase in cost, for stems having the qualities of high elastic

limit, high ultimate strength, moderate ductility, cost little if any more than those that have high ductility, moderately high ultimate strength, comparatively low elastic limit. It is not particularly difficult to get a bronze that will have a yield point of not less than 40 000 lb. per square inch, an ultimate strength of 60 000 lb. to 70 000 lb. per square inch, an elongation percentage of 10 in 2 inches, a reduced area percentage of 10; and, with the importance of having the stem retain its original shape understood, surely that is better than getting a metal which has a yield point of not over 25 000 lb. per square inch, an ultimate strength of around 50 000 lb. per square inch, an elongation of around 30 per cent. in 2 inches, a reduction of area of around 25 per cent.

It is hoped you catch the point I am trying to make, which is that the water-works official and the manufacturer usually base their calculation on the ultimate strength of the material, figuring that the usefulness of the stem is not gone until it actually fails.

This harder, stronger metal is of course somewhat tougher and not quite so easily machined, but if the proper tools are used it doesn't appreciably increase the cost, and surely is better than increasing the size of the stem beyond the manufacturer's standard, to get the added strength.

The more frequent reasons for valve-stem failures are that, as indicated, the factor of necessary strength is mostly based on the full diameter of the stem; the tensile or ultimate strength of the metal, and not taking into account that metals of any kind, unless especially treated for it, do not have as great strength in the center or core of the mass as near the surface, with the result that a stem has scarcely any greater strength at the bottom of the thread than the simple working stresses that are put on it, without taking into account added friction due to corrosion, sediment, etc., nor that in many cases the persons operating are likely to use tools that exert considerably greater leverage on the gears or operating nut than is intended or needed.

Therefore to overcome these failures, so far as humanly possible within reason, the calculations for valve stem diameter should be:

Allowance for the fact that the metal at the base of the thread does not have as great a strength as near the surface or the top of the thread; a further allowance for the use of tools for operating, which will exert greater stress than the usual tool used; together with allowances for friction due to corrosion or sediment in the water, and other factors mentioned earlier, of weight of mechanism, friction of gates and seats in operation, and friction in stuffing box, controls the area at the base of the thread, and also that a liberal allowance should be made the governing feature for factors of safety, and the metal should have a high yield point, a fairly high ultimate, and moderate ductility.

In order that the physical qualities of the bronze may be known and kept uniform, it is very important that frequent tests be made. The proper way to get the pieces for testing so as to have them as truly repre-

sentative as the stems themselves, is, where the stem is cast and large enough to do so, to have the piece for testing cast attached to the actual stem, and where the stem is of a size to make this impossible the test piece should be cast in the same heat and in the same flask as the stems. In the case of hammered or forged stems, the test piece should be a prolongation of one end of the stem reduced to a cross-section that will show a close approximate of the metal in the stem itself. It is unnecessary to go into the details of the methods of making the physical tests.

For smaller and medium-sized valve stems up to and including those for, say, 24-in. valves, a cast stem is entirely proper, but for stems for valves 30 in. and larger they should be of forged manganese bronze. Forging adds very little to the cost and adds some to the physical qualities, but their main value lies in that the forging on stems of heavy cross-section makes the metal homogeneous and of uniform texture throughout, makes a perfect metal for the threads and eliminates the uncertainties that are apt to be present in the case of large castings, where the central section is subject to different cooling stresses than the outer section.

In the foregoing I have endeavored to demonstrate the advantages of using a high-grade manganese bronze for your valve stems, and to explain that by specifying such metal no hardship is being placed on the manufacturer; in fact, if he will but stop and think it will work ultimately very much to his advantage, for what manufacturer is there that would not rather have his product praised than condemned, and his attention can be given to producing new goods, and not have to use part of his shop facilities for repair parts, for there are things that can happen to a valve outside of the stem that can be readily traced back to the stem. And to you men who use valves, by exercising care and specifying for your stems bronzes that will have high physical values, you will establish a standard which will work a considerable economy, — economy of cost, economy of long life, economy of efficiency, economy of insurance against property damage and even possible loss of life. Your coöperation and efforts, together with the coöperation of those who supply your valves, is the thing that will accomplish this.

Discussion.

Mr. J. M. Diven.* While fully agreeing with the writer of the paper that the stem is the weak point in a valve, and that they are most often put out of commission by the breaking or buckling of the stem, and that the stems should be made of the best available material and of the greatest strength consistent with economical manufacture, the speaker cannot fully agree that they are the only part of a valve mechanism that will by breaking put a valve out of commission, for the breaking of a wedge, especially the top one, or of the bushing or nut in the wedge, will quite as effectually render the valve useless as the breaking of the stem. If there is nothing for the stem to act on it cannot operate the valve.

The writer says that, in the days when valves were widely scattered on the distribution systems and controlled large territories or length of mains, they were used infrequently and were more apt to rust or set owing to inaction than with the present practice of many valves controlling short lengths of main. The reverse would seem to be the case, for two valves in present practice control each block; if they had to be used to shut down five or ten blocks there would be five or ten times more liability of leaks on the pipe lines controlled by them than if there were valves for each single block. Of course we do not now allow valves to stand idle till needed to shut off for repairs, but make frequent tests of them, which was, probably, not so universally the case in the old times.

Mr. Patrick Gear.† The trouble I find with the stem is not in the stem altogether, because you can bend that up and down for a month and the stem won't break. But instead of talking about metal for the stem, if we would only tell the manufacturers how they ought to make their gate and get them to make it properly, we would not have any trouble with the stem.

I do not think I am stepping on their toes when I tell them that there is not any improvement over the gate that they made forty years ago in the gate they are making to-day. They may test the stem and have a little better metal in it. Some of them tried to put a steel rod in the stem, some years ago, but they did away with that. If they will make the gate so that there will not be any corrosion and the rust won't come against the gate when you shut it and open it, there will be no trouble.

Mr. Van Gilder speaks of shutting and opening the gate when he has the leak. We all have that trouble of opening and shutting the gate. If the manufacturers would only make the gate properly, so that corrosion would be kept away from the face, they would be all right. I have taken off some gates that were in for forty years, and the trouble I found with one of them was that the cast-iron stuffing box had such a grip on the stem that it could not be opened and shut. And still they put a cast-iron

* Secretary, American Water Works Association.

† Superintendent, Water Works, Holyoke, Mass.

gland and stuffing box on to-day, and it is all cast iron around a brass stem, and they expect, when the packing is worn out, that it can be made tight.

If they would only make their gates all brass, so that there would not be the cast iron and brass working together, you would not have all the trouble you do.

Mr. Diven. I know of some 30-in. valves all composition. They are making them to-day.

President Sherman. I guess they will make bronze valves if you want to pay for them.

Mr. C. P. Davis.* I would like to ask Mr. Gear if he uses any grease on those stuffing boxes.

Mr. Gear. Not on those that have been in the ground for thirty or forty years, in concrete streets. When we put in a new gate we use all the precaution that is required. You need brass bands, brass bolts, and brass nuts to get the best stuffing box, with brass lining under the shoulder of the spindle, — the top of the gate where the shoulder sets down. Forty years from now there will be no trouble, because there is no packing there now. The shoulder of the spindle up against the brass lining of the top of the gate will make it tight.

Mr. Davis. I think there is much to be gained from the lubrication of those parts. We have the cast iron against the brass or bronze, or whatever it is. We all know that the great majority of the valves have very little provision for lubrication. Isn't it time that we took some step not only to see that we get proper lubrication in new valves but to lubricate the valves already on hand?

President Sherman. Can you do much in the way of lubrication of a valve that has only a cast-iron gate box over it? I believe the majority of our valves have only the cast-iron box.

Mr. Davis. Shouldn't we provide some covering, like a waterproof tar or cotton stock?

President Sherman. I was wondering how you expected to get the grease into it.

Mr. Davis. I think all valves should be in a box large enough to give easy access, without breaking the pavement, to the mechanical parts of the valve. Pavements are becoming more and more costly. It probably costs \$25 or \$30 every time you break the pavement. I think it pays to put them in a valve box.

President Sherman. I think that is a great point, but most of us are not doing it in small places.

Mr. Davis. At present prices it costs about \$30 or \$40 to make a good valve box, to give you access to all the mechanism of a large valve, and completely to the small valve.

President Sherman. What kind of box do you use?

* Chief Bureau of Water, Philadelphia, Pa.

Mr. Davis. We use a reinforced concrete box of sectional rings. The bottom course is split to straddle the pipe, and subsequent courses are split on opposite axes for bonding. The cover is a reinforced concrete slab about 4 in. thick, with a hole for the cast-iron manhole frame and cover similar to that used for sewers. The box is about 2 ft. by 3 ft. inside.

Mr. Diven. I used one of cast iron. I don't know whether it is still on the market or not. You can build it up to any size you want. It allows space to get into, to oil the valve or take the stem out of an upright valve. In one case I had a valve that gave a great deal of trouble. The stem gave out twice and I had to take up a lot of concrete paving. The last time I fixed the valve I put a piece of 4-in. pipe in so that the stem could be run out into this 4-in. pipe to save tearing up the street if we had further trouble.

A RATING OF THE QUALITIES OF THE WATER SUPPLIES OF MASSACHUSETTS.

BY GEORGE C. WHIPPLE.*

[*Read September 15, 1921.*]

It is a long time since a critical review of the water supplies of Massachusetts with reference to quality has been published. The State Department of Public Health has continued to make analyses of samples of water in much the same way as they were begun thirty years ago, but in recent years fewer samples from each source have been analyzed and some of the early tests have been omitted. Parsimony in state printing has made it necessary to emasculate the reports of laboratory work, with the result that the Department of Public Health has lost in prestige, the public is not as well informed in regard to the quality of the Massachusetts supplies as it once was, and the records are not as readily available for scientific study as they ought to be. In 1891 the annual report of the State Board of Health devoted 190 pages to the analyses of domestic water supplies; in 1901, 98 pages; in 1909, 52; and since that date, 8 pages. The last comparative study was published in 1909. For the last ten years, only the yearly averages of a portion of the tests made in the laboratory have been published.

It is not now necessary to publish the analyses in the detailed manner of thirty years ago, when the subject was new, and it is not necessary to print each year comparative average figures for the previous years, as was formerly done; but the public is entitled to have, and ought to have, something better than it now gets. A satisfactory plan might be to publish each year the results for that year, making mention of any abnormal or unusual conditions, and then once in five years to publish comparative tables of the analyses for the previous five years, accompanied by a critical review of the qualities of the different water supplies. According to this plan, a quinquennial review of the water supplies for the five years ending December 31, 1920, would now be due; but inasmuch as no such summary of reports was made in 1915, this should cover a ten-year instead of a five-year period.

Since the last comparative tables were published in 1909 there have been almost no changes in the art of chemical analysis which it has seemed worth while to introduce in the State Department of Health laboratories. The Committee on Standard Methods of Water Analysis of the American Public Health Association has suggested certain minor modifications in methods of procedure, but their adoption would have made it difficult to

* Professor of Sanitary Engineering, Harvard University.

compare the new results with the old and, because of the long series of analytical records in Massachusetts, uniformity with the past seemed to be more important than uniformity with methods used in other states. For the same reason also the method of stating the results in parts per 100 000 instead of parts per million has been adhered to, although the writer personally favors the latter method and has used it in this review.

Bacteriological methods have never been held to the same rigid system which has been followed in chemical analysis. There are more uncontrollable variables in bacteriological work. In these tests the Department of Public Health has followed the changes recommended by the Committee on Standard Methods in a general way, but these changes have been so frequent that it has not seemed wise to break continuity with past records too frequently.

While improvements in methods of analysis have not been great, a decided change has taken place in the attitude of American sanitary engineers towards water analyses. This altered viewpoint is exceedingly important, although it is somewhat difficult to put into words. In the first place, there has been a shifting of the emphasis from the chemical to the bacteriological tests, as being more definitely indicative of the sanitary quality of the water. There has been a growing feeling that the old method of "interpreting" the chemical analysis was too speculative, and that the nitrogen tests were too liable to be upset by disturbing conditions to make them trustworthy as a basis of interpretation. At the same time the reliability of the bacteriological tests has failed to become fully established. In short, there has been a loss of confidence in water analyses as an index of the wholesomeness of unpurified waters. Fortunately, as a result of various sanitary reforms, prominent among which is water filtration, there has been a notable reduction of such diseases as typhoid fever.*

Throughout the United States there has been a great extension of the practice of water filtration. Water analyses have been found essential to the proper control of filter operation, but the tests useful for this purpose are quite different from those used as a basis of interpretation of the wholesomeness of unfiltered waters. In water filtration the nitrogen determinations have little or no value, but the bacteriological and microscopical tests, the chemical tests of hardness, alkalinity, and free carbonic acid, and the physical tests of color, turbidity, and odor are important and are being made throughout the country in enormous numbers.

In places where the water supply has been made reasonably safe against infection, public interest in the quality of the supply is shifting from its sanitary quality to some of its less important but more obvious characteristics. One reason for this is that filtration, while making water supplies safe, also makes them clean. The inhabitants of cities are becoming

*The average typhoid fever death-rate for the state of Massachusetts in 1920 was 2.5 per hundred thousand. The highest death-rate in any city was 10.7, and only five cities had death-rates about 5 per hundred thousand.

accustomed to clean water, water which has little color and a brilliancy not found at all times in unfiltered surface waters. Many communities also are supplied with ground waters, which are clear, colorless, brilliant, and odorless, except in some places where there is trouble from iron or manganese. Without doubt the popular standard of purity of public water supplies is steadily rising. Algæ growths continue to cause complaint in many places on account of the odors which they produce. It is the writer's opinion that in Massachusetts, where the safety of the public water supplies is well assured, the people will not and ought not to be content until the water furnished is practically free from odor and vegetable stain and is as good in appearance as the water in the cities, once supplied with muddy water, which are now enjoying the benefits of filtration.

There is one other property of water which is attracting increasing attention, — namely, its corrosiveness. Plumbing is far more common than a generation ago, the amount of money spent annually in the United States for plumbing supplies running into millions of dollars; the materials used for piping have undergone changes, lead being replaced by iron and steel, and brass pipes being much used; hot-water heating has become more common; plumbing repair costs have increased; the use of meters has shown that the leakage of water is greater in the houses than in the street mains. The use of ground water and mechanically filtered waters, which in Massachusetts are more corrosive than ordinary surface waters, has increased the problem of corrosion. All of these things are tending to give the corrosion factor a greater prominence than it has ever had before. In the future it must be reckoned with as one of the major elements of the water-supply problem. It must be attacked from both sides, — that of the quality of the water supplied and that of the character of the materials used for conveying and using water.

In making a rating of the qualities of the water supplies of Massachusetts, then, we have four major items to consider, — namely (1) sanitary quality, (2) general attractiveness, (3) mineral constituents, and (4) corrosiveness.

Rating of Sanitary Quality.

The "sanitary quality" of a water supply is the term by which we describe its likelihood of conveying disease germs from some source of pollution to the water consumers. It is fundamentally a bacteriological question. If bacteriological tests were not so imperfect, it would be possible to base a sanitary rating of the water on these tests; but inasmuch as the infection of a water supply is rarely constant but occurs suddenly and usually without warning, no rating, especially if based on analyses alone, can be regarded as perfect. It may be worth while to consider some of the underlying principles as we now view them.

The presence of disease-producing organisms in water cannot be reliably determined by analysis. Certain relatively harmless bacteria of fecal origin, such as *B. coli* and *B. Welchii*, can be detected in water, but there are no ready methods of accurately determining the number present, and there are no methods for distinguishing between those derived from human excreta and those derived from animals or birds. Nevertheless, these tests, although somewhat uncertain bacteriologically and unsatisfactory statistically, are of much use as an index of the likelihood of infection. The presence of bacteria that will grow on culture media at the temperature of the human body is another index, and the presence of bacteria that will grow at room temperature is still another, but is less definite as an indication of danger. All of these bacteriological tests, to be of value, must be made at frequent intervals, often enough to cause the analytical results to reflect the natural changes in the quality of the water. In local laboratories, such as exist at all large filter plants and in some cities where the water is not filtered, these frequent tests can be made at a reasonable and justifiable cost, but obviously it is an expensive method of control if conducted continuously on a state-wide basis.

The bacilli of typhoid fever and other known water-borne diseases do not multiply in water but decrease at a nearly constant percentage rate from day to day, the rate varying with temperature and light, with the substances present in the water, and doubtless with factors still unknown. The rate of decrease is usually lower in winter than in summer. Under average conditions it may be considered as about 20 per cent. per day. At this rate, after one day's storage 80 per cent. of the bacilli would be left; after two days' storage, 80 per cent. of 80 per cent., or 64 per cent.; after one week, 21 per cent.; and after one month, 0.12 per cent.; etc. There is no way of determining by analysis this "age of pollution." Many will remember the words which Dr. Drown so commonly used, "The state of change is the state of danger." By comparing the four tests for nitrogen and observing whether a considerable proportion of it was present in the intermediate stages known as free ammonia or nitrite, he made inference as to whether the organic matter was in a state of change, — that is, whether the pollution was probably recent. Such inferences are often sound, and the methods are as good to-day as they ever were, but they are interfered with to a considerable extent by growths of algae in surface waters, and by bacterial reduction of nitrate in ground water, so that taken by themselves they are not very trustworthy. As a matter of fact, the probable age of pollution in surface waters can in most cases be determined quite as well by inspection and by hydraulic methods, unless the pollution accidentally occurs in the reservoir itself or near the intake, as might happen in the case of boating, fishing, ice-cutting, and the like.

The "population per square mile" on a watershed is a useful index of the opportunities of infection, and may be regarded as the basic measure of the danger at the source. This must be multiplied by one or more

factors of safety, which depend partly upon natural and partly upon artificial conditions. The natural conditions include character of the soil, the slopes of the watershed, the size and shape of the reservoirs, the nominal storage period, and other minor influences which together control the time required for pollution to reach the consumers. The nature of the soil is a matter of great importance, — sandy soils, and even gravelly soils, affording much higher factors of safety than tight, clay soils. Storage reservoirs which have a straight axis are less effective in their sanitary protection than those which are curved, as there is more danger that winds may drive the water quickly from the inlet to the outlet without mixing, and thus reduce the age of the water. In a curved reservoir, or one which has irregular shores or promontories between the inlet and the outlet, as at Fresh Pond, Cambridge, there is less chance that the incoming water will pass to the outlet unmixed with the water already in the reservoir. Mixture results in the wide dispersion of any pollution, as well as longer storage. The artificial conditions include methods used by the people living on the watershed for disposing of fecal matter. For equal populations, towns and villages, if they are sewered into the streams used as water supplies are more dangerous than isolated farms, but they are less dangerous if they are sewered and the sewage diverted from the watershed. An uninhabited watershed ought not to be considered as wholly without danger, because of the chance that people may wander over it in the course of boating, fishing, ice-cutting, hunting, automobiling, and so on.

The writer and his students have attempted to express these various factors in figures, but the problem is so complicated and the necessary data so difficult to secure that none of the results are worth publication. It is necessary to fall back upon the exercise of judgment in each particular case, striving always to reduce the chances of pollution and increasing all possible factors of safety. In spite of difficulties in weighting and combining the various factors into a mathematical sanitary index, it is important to recognize that long experience has proved that the natural factors of safety are of real and substantial value.

It is interesting to compare the index method of studying the potential danger of infection of a water supply with that used by Stearns and Drown some years ago. As a check on "persons per square mile" they used the "excess of chlorine" above the normal of the region. They found that each person per square mile increased the chlorine by 0.005 part per million (State Sanitation, II, p. 139). They could not very well use the nitrogen determinations to obtain the time factor of safety because of the interference of the algæ growths and for other reasons, but it is evident that in their discussion of the analyses they did make a mental allowance for a time factor based on the nitrogen determinations, calling it, however, the "state of change," which meant a state of danger.

There is another factor which enters into the problem of safety from infection, the factor of *chance*. It is not possible to compute with a satis-

factory degree of precision the chance of infection of a water supply. It is not the average condition which produces an epidemic: it is some exceptional combination of conditions. The frequency with which these may occur is not subject to computation. It may be asserted, however, that water supplies which are uniform in quality as shown by analyses are safer than those which show wide fluctuations from time to time, just as reservoirs which are always full are safer than those which are sometimes nearly empty, and just as people who live a regular life are less subject to untimely death than those who are irregular in their habits. It is possible to study the variations in the quality of water by applying the laws of probability to the results of analyses when these have been made with regularity over a long period of time. Variations in color, chlorine, organic matter, nitrogen as free ammonia, and especially in bacteria and *B. coli* give opportunities for studying the fluctuations in quality, which may be due to increased discharge of water from swamps, increased washing of the soil, sudden movements of water across a reservoir, effects of unusual pollution, or other causes. In the same way variations in the quantity of water stored in a reservoir and even variations in rainfall are an index of unsafe conditions. It would be well to adopt as a guiding principle a paraphrase of Dr. Drown's dictum, and say that "*a state of irregularity is a state of danger.*"

These same principles may be applied to surface water supplies protected by filtration. The potential danger of a filtered water depends upon the density of population on the watershed, multiplied by a factor of safety supplied by the filter. The value of this factor may be taken as the per cent. which the number of bacteria in the filtered water is of the number present before filtration. Ordinarily this will not exceed 1 or 2 per cent. under average conditions, and will often be much less than 1 per cent. But here again the element of chance comes in. Some filters work steadily and give results which do not vary much in efficiency from day to day; other filters, because of being ill adapted to the service, poorly designed, or poorly operated, or, perhaps, because of being outgrown, give results which vary considerably from day to day or even from hour to hour. Here also one may say *the state of irregularity is the state of danger.* Large filters are usually more uniform in their performance than small filters, just as large storage reservoirs are usually more uniform in the quality of their water than small reservoirs. Hence with small supplies the population factor is of greater importance than with large supplies. Superintendents of small water works need to protect the original sources of their water supplies with especial care.

As to chlorination, it may be said that the process furnishes a high factor of safety under average conditions, but that the factor of irregularity is a more serious one than in the case of filtration. If chlorination fails, as it sometimes does for short periods, the factor of safety is reduced to zero. If this process is to be depended upon, this serious element of

irregularity must be overcome. Of course, the combination of filtration and chlorination multiplies safety, but the policy of cheapening filtration, utilizing it for clarification only and depending upon chlorination for bacterial purification, is one that is attended with great danger, and ought not to be followed.

Unfortunately, the factor of safety of water-purification works of any kind involves the human element, which is somewhat erratic, and especially liable to be so in small plants where the attendance is not constant and where the operation is necessarily left to persons who are not expert in the special field of water purification.

Massachusetts with her many small supplies has very properly placed the chief emphasis on the protection of the original sources of the water, has emphasized sanitary inspections, has favored the acquisition of land for protecting water supplies, and has been opposed to such dangerous practices as boating, fishing, and ice-cutting on reservoirs. As the state becomes more populated, as the cities become larger, it will doubtless be necessary to add to the natural factors of safety those which are obtained by various methods of purification. In some cases these have already been adopted. Massachusetts is fortunate in having favorable soil conditions and storage facilities for water-supply purposes.

Attractiveness.

The word "potability" was first used to describe the "drinkable" characteristics of water, and had reference to certain very obvious qualities. Water which is lukewarm is not drinkable; neither is water which tastes or smells bad or which is offensive to the sight. Sea water is not potable. Popularly speaking, an infected water, however, may be potable, — as, for example, an infected well water. In recent years the term "potability" has been widened to include the sanitary quality, the safety, the wholesomeness, in fact, all of the qualities of a public water supply, and the result has been that a perfectly good word has gone out of current use in America. Now, when we wish to describe the potability of water, we speak of its attractiveness, its "esthetic" qualities. When people say, as they so often do, that "We have the best water in the state," or "We have the best well in the village," it is attractiveness which they have in mind, not safety from infection. When the time comes that all public water supplies are reasonably safe we may be able to restore the word "potability" to current use.

There are several properties which combine to make up this quality of attractiveness:

1. Color, measured by comparison with standards.
2. Clearness, measured by the turbidity test.
3. Brilliancy, for which there is no accepted test.
4. Odor, due in great measure to microscropic organisms.

5. Taste, due largely to dissolved organic or mineral matter.
6. Aëration.
7. Temperature.
8. Esthetic surroundings of the source.

Of these properties, color, turbidity, aëration, and temperature can be measured with accuracy. Taste and odor can be described in simple, approximate terms, but cannot be measured accurately. Brilliancy is a quality which we may some day learn how to measure. It is due apparently to an absence of colloidal clay and finely divided organic matter. It is probable that by the further development of the Tyndall ray we shall be able to measure, as well as indicate, the amount of these colloidal substances. Every one knows how dust particles in the air over a hayloft can be detected by the ray of sunlight which enters through a crack in the barn. That is the principle of the Tyndall ray, and also that of the ultramicroscope. Brilliancy is a sort of extension of the idea of clearness. Some waters are clear, — that is, they have no turbidity, but they are not brilliantly clear; they do not sparkle. As Houston says, filtered waters ought to have a "clean, polished look." Some colored waters are brilliant, just as tea is brilliant, or that ancient liquor known as beer. Therefore not all colloidal matter interferes with this quality of brilliancy.

The sparkling of water is due to brilliancy coupled with aëration. Very finely divided bubbles of air emerging from solution reflect the light and make the water sparkle. Spring water, being cold, contains more dissolved air than it can hold in solution after it has been warmed. Consequently these gases come out of solution, appear as minute bubbles which sparkle, and then coalesce to form larger bubbles visible to the eye, and perhaps collect on the sides of the glass. We do not reach perfection in water purification until we produce water like the "sparkling spring." Artificial aëration will make a brilliant water sparkle.

The various qualities which combine to make up the attractiveness of water are of immediate and daily concern to the consumers. Experience has shown that some people demand a water which closely approaches the ideal of attractiveness; others make no remark at slight departures from the ideal, but complain if the water is dirty or too highly colored or has an odor. A point may be reached, however, when, because of excessive color or turbidity or because of bad odors, nearly all persons object to the quality of the water, — that is, the water becomes non-acceptable, non-potable. There are also persons who have a natural repugnance to drinking water from a polluted source, even though assured that the water is safe and even though it is delivered in a fairly satisfactory state. The esthetic surroundings of a water supply are elements of real value.

It is possible to set fairly definite standards for the obvious qualities of color, turbidity, and odor. It might even be possible to combine them into an index of attractiveness and use it for comparing different water supplies. Such comparisons are more curious than useful, for each

community must draw its water supply from naturally restricted sources and must also look well to the cost of its water service. Nevertheless, it is important that every supply be made attractive to the consumers, and in the long run the consumers are the best judges. It is not for the engineers and chemists to set the standards of attractiveness, but to register the opinion of the consumers, bearing in mind that communities differ in their ideas just as people differ.

While the ideal color is zero, waters which have colors less than 10 are nearly always regarded as practically colorless. Colors between 10 and 20 are acceptable in New England provided that the waters are not also turbid. Dirt and microscopic organisms in water accentuate color. When the color exceeds 40 or 50, or even when it exceeds 20 with suspended matter present, the water is not satisfactory for drinking, as it looks dirty in a glass or in a porcelain washbasin or bathtub.

New England waters are seldom as turbid as those of the South and Middle West, where the soil contains much clay. The glacial drift which covered the northern part of the country did much to guarantee attractive water supplies. Such turbidity as is found is usually of such a character that it quickly settles on standing and forms a sediment. It is difficult to measure this sediment by the standard silica scale, and the analysts have taken recourse to descriptive words such as slight, distinct, heavy, etc. As a rule, according to Mr. H. W. Clark, these terms correspond to weights of sediment about as follows:

Very slight	0– 2 parts per million.
Slight	3– 10 parts per million.
Decided	11– 50 parts per million.
Considerable	51–100 parts per million.
Heavy	101 parts per million.

Turbidity may be due to microscopic organisms, and this has also been described in words, such as very slight, slight, distinct, decided, etc. Hardly one sample in twenty has turbidity enough to enable it to be expressed on the numerical scale.

The turbidity and sediment in water is subject to seasonal fluctuations and is influenced by the erratic occurrence of microscopic organisms and soil washings after heavy rains. In classifying the water supplies of the state according to turbidity, the best method appears to be to record the per cent. of time during which certain conditions prevail.

No attempt has ever been made to measure brilliancy. This is a quality which needs to be studied. Waters which contain both color and turbidity are dull or "murky."

Nearly all ground waters are brilliant unless they contain iron or manganese. Very few of the surface waters of New England are constantly brilliant, because of microscopic organisms or other organic matter, but they can be made so by filtration. Some waters lose their brilliancy by picking up iron rust from the distribution pipes. A water may have a

color above 20 and yet be brilliant. Brilliancy is a quality much desired and highly prized. A brilliant water of color 30 is liked better than a dull water of color 15. It is not possible to classify Massachusetts waters according to brilliancy in a reliable way on the basis of present data.

Growths of microscopic organisms are characteristic of the surface water supplies of New England. They occur intermittently, and vary greatly in different reservoirs. Some of them merely make the water dull or murky; others give rise to odors characterized as grassy, aromatic, fishy, etc. Decaying organic matter, including decaying organisms, give moldy odors. Even the harmless organic matter which produces color gives to water a vegetable or swampy odor. All of these odors vary in intensity as much as they vary in character.

It would be possible to classify the waters of the state according to the number of organisms present, but as there are many species of organisms it would require an elaborate study. The organisms are fragile and are often destroyed during the transportation of the samples, so that the results of analyses are not always true. Furthermore, the State Department of Public Health has never adopted the standard unit system of keeping records, the most satisfactory method yet devised. Hence the published results have only a general value for purposes of comparison. It will therefore be more practical to classify the water supplies according to the odor test, even though the odors are subject to change during the transportation of samples and also subject to a personal equation, the sensitiveness of the sense of smell of the water analyst. As a rule the algæ odors as observed by the analyst are less pronounced than those observed by the consumer taking a glass of water directly from the tap, — just as the flavor of strawberries purchased in the city is not as sharp and delicious as when the berries are first picked. Moldy odors, on the other hand, become intensified when water stands in a closed bottle.

The most useful basis for comparison seems to be the per cent. of time during which the water supplies have possessed odors of different degrees of intensity. This assumes that all odors are objectionable, whatever their character; that "very faint" and "faint" odors are noticeable; and that "distinct" and "decided" odors are objectionable. Thus by putting together the weekly odor records kept in the laboratory of the Metropolitan Water Works during the years 1905 to 1920, and dividing them into five classes, A, B, C, D, and E, we get the following results, which have been computed from data furnished by Mr. Charles E. Livermore.

ODOR TESTS, METROPOLITAN WATER WORKS, 1905–1920.

(Figures indicate percent of lime.)

	A. Practically no odor.	B. Odor too faint to attract attention.	C. Odor noticeable but not enough to cause complaint.	D. Odor strong enough to cause some complaint.	E. Odor strong enough to cause general complaint.
Wachusett Reservoir	4.4	85.8	5.8	3.2	0.8
Sudbury Reservoir	1.5	73.3	15.2	9.0	1.0
Framingham Reservoir, No. 2	1.0	80.7	10.0	8.1	0.2
Lake Cochituate*	0.4	38.8	29.5	23.6	7.7
Chestnut Hill Reservoir	3.0	84.4	8.2	3.5	0.9
Spot Pond Reservoir	3.0	78.2	13.2	4.8	0.6
Tap, 180 Boylston Street	1.9	84.7	8.0	4.9	0.5
Tap, Ashburton Place	1.7	84.5	7.4	5.6	0.8

These figures show that in the Metropolitan District the odor of the water is strong enough to be noticeable and cause some complaint for two or three weeks each year.

MINERAL CONSTITUENTS.

The surface waters of Massachusetts are not highly mineralized. The mineral solids seldom exceed 75 parts per million. In the Berkshire district, where there are limestone deposits, the surface waters are a little harder than elsewhere. The ground waters are naturally harder than the surface waters. The hardnesses of the wells vary somewhat erratically. Wells near the coast are inclined to be hard. Household wells that are polluted are also hard.

The term "soft" may be logically applied to waters which have a hardness of less than 12 parts per million, this being about the limit of the solubility of normal calcium carbonate. The terms for the other classes have local application only. Popularly speaking, hardness is a relative term. All Massachusetts waters would seem soft to people accustomed to the hard waters of the Middle West.

Iron and manganese are elements which give rise to more or less trouble in our Massachusetts water supplies. These troubles are confined chiefly to ground waters.

CORROSION.

According to modern theory, the corrosion of metals is incited by the presence of hydrogen ions in water. Ions carry electrical charges, hence the phenomena of corrosion are properly regarded as electrical. When two different metals in contact, or even without being in contact, are immersed in water which, because of the presence of electrolytes, conducts electricity, galvanic corrosion will occur. If a current of electricity is passed through the system, corrosion will be accentuated. The actual

* Held as a reserve supply and seldom used.

rusting of iron is brought about by the oxygen dissolved in the water, and it may be said that most water supplies are fully charged with dissolved oxygen.

Until within a few years it was not regarded as practicable to measure the amount of the hydrogen ion as a routine laboratory procedure. It

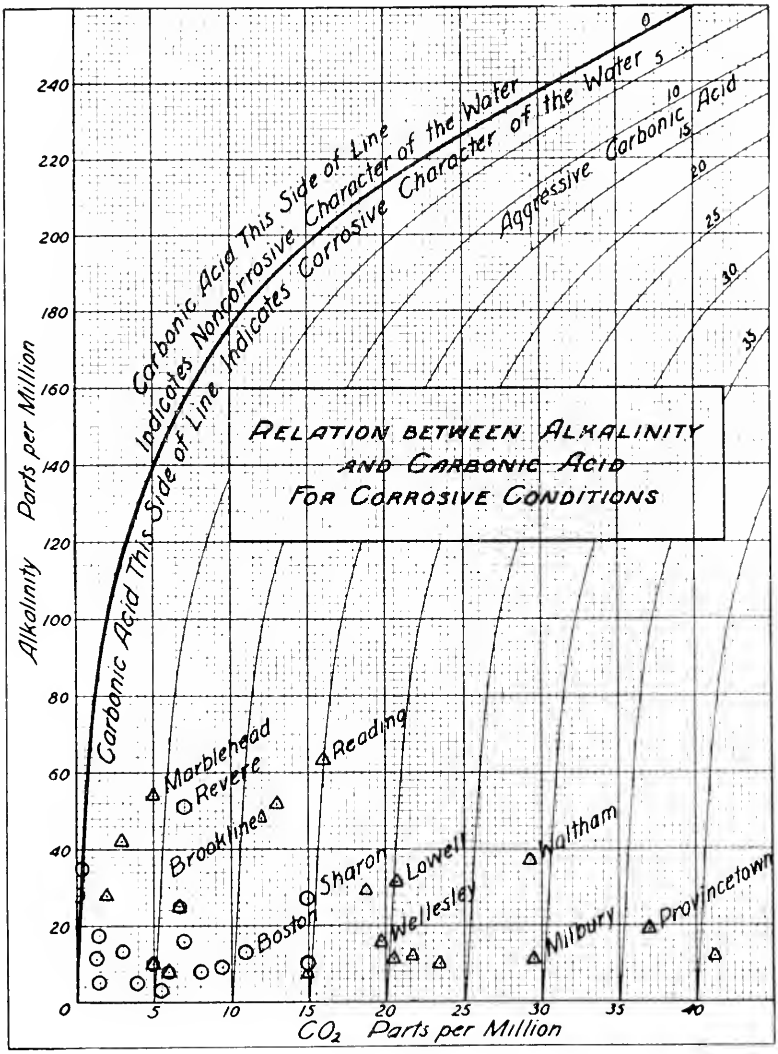


FIG. 1.

is now possible to do so, and the test is easily made. A hydrogen ion survey ought to be made of all of the water supplies of the state and extended through an entire year in order to obtain the effect of seasonal changes.

But even without such a survey it is possible to compare the relative corrosive powers of waters on the basis of certain chemical tests which

have already been made, — namely, carbonic acid, alkalinity, color and chlorine. The presence of dissolved free carbonic acid means that hydrogen ions are present. The presence of chlorine (actually chlorides) means that the water will conduct electricity and that galvanic action may occur. Alkalinity (due to calcium or magnesium carbonates and hence making up part of the hardness) retards corrosion. Coloring matter means organic acids and more hydrogen ions. Hence soft waters which contain free carbonic acid or coloring matter are corrosive. Waters near the sea, or well waters that are polluted, are corrosive because of the presence of chlorides and accompanying salts. Hard waters are less corrosive, even though carbonic acid and chlorides are present.

The free carbonic acid in water is subject to great variations. In surface waters, exposed as they are to the air, it seldom exceeds 2 to 5 parts per million, as the water is delivered to the city. The stagnant strata of water near the bottom of a reservoir may contain ten times as much as this. Well waters usually contain much more carbonic acid than surface waters, and the amount is subject to most erratic changes, so that only by making a large number of tests can the average amount be fairly determined. Such tests have the disadvantage that for exact results the operations must be performed on samples at the time of collection and not on samples sent to the laboratory. Many of the surface waters have their carbonic acid reduced to zero during the summer by reason of growth of algæ.

Recent studies have given a basis for estimating the combined corrosive effect of carbonic acid and hardness, — the one corrosive, the other protective. For any given amount of carbonic acid there is a corresponding hardness which will furnish protection. This relation is shown by Fig. 1. If for any given hardness the carbonic acid is more than that shown by the curve, the excess may be termed " aggressive " and the water will be corrosive. In some sections of the country where the waters have a hardness of one or two hundred parts per million there is very often no aggressive carbonic acid, but with the soft waters of New England nearly all of the carbonic acid is aggressive. To make an appraisal of the water supplies of the state from the standpoint of corrosion is not easy. The basis of such a comparison is obtained by using the chemical determinations of carbonic acid, chlorine, alkalinity, and hardness.

Our knowledge of these matters is not yet sufficient to enable us to classify adequately the waters of the state on the basis of their corrosive power, but a few generalizations may be made. Waters are corrosive in proportion to their aggressive carbonic acid and in proportion to the chlorides present. The hard surface waters of the western part of the state are low in chlorine and are but slightly corrosive. The soft surface waters of the middle and eastern portions of the state are slightly corrosive during the greater part of the year because of the presence of small amounts of aggressive carbonic acid. The well waters of the state, although gener-

ally harder than the surface waters, are more corrosive because of the presence of more aggressive carbonic acid. Pollution increases the aggressive carbonic acid. Ground waters taken from infiltration galleries near rivers or wells located in swampy places are especially liable to contain aggressive carbonic acid. Alum-treated waters contain more aggressive carbonic acid than before treatment, as the alkalinity is reduced and the free carbonic acid increased. Water supplies near the coast and polluted waters have their corrosive power increased by reason of higher chlorine contents. The next few years ought to show a marked increase in our knowledge of this subject.

The subject of lead poisoning is connected with that of corrosion. Much attention has been given to it in Massachusetts, especially in the early days. There is less lead poisoning from public water supplies now than formerly, largely because less lead pipe is used in house plumbing; but the matter is one that should not be allowed to drop out of sight. In some cities it is still important, and in a few places it is of serious import. In Providence the water is artificially hardened in order to reduce the aggressive carbonic acid. This practice will some day become more common than it now is.

Classification of Massachusetts Waters.

Having considered the various elements involved in a rating of the quality of water from the standpoint of the consumer, we may now turn to the water supplies themselves and set forth some of the results for the purpose of comparison, by means of tables and diagrams. These data were compiled by Miss Bertha M. Brown, C. P. H., recently a student in the School of Public Health of Harvard University and the Massachusetts Institute of Technology.

For the sake of simplicity the supplies were divided into five classes, A, B, C, D, and E (represented by the colors: blue, green, yellow, orange, and red on the maps*), for each of the analytical tests considered. These classes were intended to represent the qualities of the water from good to bad, — classes A and B being satisfactory, classes D and E being unsatisfactory, and class C being intermediate between the two.

The analytical values used in making this classification were as follows:

Significance of Colors Used on Classification Maps.

Class		Turbidity or Sediment.	Odor.	Color.	Parts per Million		
					Hardness.	Iron.	Chlorine
A	Blue	None	None	0–10	0–5	0.00–0.10	0–5
B	Green	Very slight	Very faint	11–20	6–12	0.11–0.40	6–10
C	Yellow	Slight	Faint	21–40	13–25	0.41–1.00	11–15
D	Orange	Distinct	Distinct	41–60	26–50	1.01–2.00	16–20
E	Red	Decided	Decided	61	51	2.01	21

* These maps were displayed at the meeting, but are not here reproduced.

On the maps the circles indicate surface waters, the triangles ground waters. These are sometimes divided into proportional parts, shown in different colors and corresponding to the percentage of time during which the different conditions prevail during the year. The intention has been to show the quality of the water as delivered to the consumers, and the circles and triangles are placed over the city or town supplied, regardless of the location of the source. The data used in preparing the maps are given in tabular form, beyond.

No attempt will be made here to compare one supply with another, but each superintendent of water works will doubtless be interested to see where his supply stands in the list. Certain general explanations of the tables and maps, however, should be made.

No comparisons of sanitary quality are given, as no acceptable index has been found suitable for the purpose. Furthermore, the various factors essential to such an index are not known in so many cases that computations are practically impossible. The sanitary quality of each water supply must still be regarded as a matter of estimate and judgment, based on all of the local conditions.

In the case of color, hardness, chlorine, and iron, the averages of the monthly analyses were used. As a rule, the figures for chlorine and hardness vary but little from month to month or from year to year. The color of surface waters varies seasonally and the variations are considerable. Thus one of the supplies (Cambridge) included in class C on the basis of its average color would be placed in the other classes during a certain part of the time, as follows: A, 0 per cent.; B, 5 per cent.; C, 90 per cent.; D, 5 per cent.; E, 0 per cent.

The data show that practically all of the unfiltered surface supplies are unsatisfactory at times by reason of odor, turbidity, and sediment, and that many of them are in the unsatisfactory color class, while most of the ground waters are satisfactory in all these respects. These qualities which go to make up the attractiveness are controllable.

Variations in Quality.

The writer has taken pains to emphasize the importance of regularity in the quality of a water supply. A water which always has a color of 15 is liked by the consumers better than one which has an average color of 15 with variations from 5 to 30. Consumers are apt to judge a water supply not by its best but by its worst condition. To study all of the water supplies of the state from the standpoint of regularity would be interesting and would go a long way in determining the relative safety of the different supplies. The writer wishes to urge each water-works superintendent to study the analyses of his supply from this point of view. Two examples may be given to illustrate the method of procedure. The first is a comparison between Wachusett Reservoir, which represents a water

of uniform condition, and Worcester, which represents a water of variable condition, the test for chlorine being used. The second is a comparison between the color of the raw and filtered water at the Springfield filter.

In Wachusett Reservoir during the years 1903–1920 the median amount of chlorine present was 2.72 parts per million, but during one tenth of the time this figure was exceeded 20 per cent., and during a hundredth of the time by 37 per cent. In Tatnuck Brook Reservoir of the Worcester supply the median value was 1.49 parts per million, but during one tenth of the time this value was exceeded by 50 per cent., and during a hundredth of the time by 60 per cent. This and other similar studies show how much more uniform in quality the larger supplies are than the smaller supplies.

At Springfield during the year 1912 the raw Little River water had a median color of 31, but one tenth of the samples had colors of less than 20 and another 10 per cent. had colors higher than 55, the extreme colors being 16 and 95. In the case of the filtered waters, however, the median color was 15. One tenth of the samples had colors less than 13, and one tenth more than 18, the extremes being 10 and 30. In other words, the filtered water was not only lower but more uniform in color than the raw water.

Certain constituents of surface waters, as, for example, chlorine, hardness, and other mineral substances, vary but little from month to month, and frequent analyses are not necessary. But color, odor, microscopic organisms, and bacteria are constantly varying, and more frequent sampling is needed if these changes are to be followed.

The Question of Filtration.

Comparatively few of the surface-water supplies of Massachusetts are filtered. Of the large supplies there are only three. The Lawrence filter was built in 1892 as a protection against the gross pollution which the Merrimac River receives. In spite of the fact that this water can be made safe by this process supplemented by chlorination, the supply is not favorably regarded by the citizens, for sentimental reasons. They say that they do not wish to drink the sewage of Lowell, however thoroughly purified. The Springfield filter was built in 1909, largely to improve the attractiveness of the Little River water, but also to secure an added factor of safety against pollution. By means of coagulation with a small amount of alum and slow sand filtration the color has been kept at a nearly uniform figure and the water has been made brilliant. It has a high factor of regularity. The Lowell filter was built in 1915 and the Brookline filter in 1917 to remove iron and manganese from ground waters. The city of Cambridge has a filter under construction. There are several smaller filters in the state built to remove iron from ground waters or to clarify

surface waters. The filters in Masachusetts on January 1, 1921, were as follows:

FILTERS IN MASSACHUSETTS ON JANUARY 1, 1921.

City or Town.	Date of Installation.	Type of Filter.
Athol	1887	Mechanical.
Cohasset	1914	"
Reading	1896	"
Scituate	1913	"
Brookline	1917	Sand filters for removal of iron.
Lowell	1915	"
Marblehead	1909	"
Middleborough	1915	"
Athol	1912	Slow sand filters for filtration of surface waters.
Lawrence (2)	1892, 1893	
Milford	1895	"
Northfield (East)	1915	"
Norwood	1913	"
Southbridge	1908	"
Springfield (Ludlow)	1906	"
Springfield (Little River)	1909	"
West Springfield	1907	"
Attleborough	1908	Filters to which surface water is applied to supplement ground sources.
Bedford	1909	
Greenfield	1913	
Hingham	1903	"
Leicester (Cherry Valley)	1912	"
Newburyport (2)	1908	"
Salisbury	1915	"

In addition to the above there is a slow sand filter at the Bridgewater State Farm, and the Metropolitan Water and Sewerage Board maintain open sand filters for filtration of brook waters entering Lake Cochituate in Natick, Sudbury Reservoir in Marlborough, and Wachusett Reservoir in Sterling. There are also certain experimental filters not listed above.

The question, "Why are there not more filters in Massachusetts?" is one that is asked outside of the state more than within the state. As a matter of fact, the water supplies of Massachusetts taken as a whole are well safeguarded and reasonably satisfactory to the consumers. The very low typhoid fever death-rate of the state has already been referred to. Yet, looking at the data for color, turbidity, sediment, and odor, it will be seen that very few of the surface waters are attractive at all seasons of the year. In almost every case there are some weeks or months in the year when the color is too high, when the water is not clear, or when, on account of growths of microscopic organisms, the water has an unpleasant odor. Even the water supplied to the Boston Metropolitan District is no exception, as microscopic organisms appear in large numbers in Wachusett Reservoir and the other reservoirs every few years. Lake Cochituate water in recent years has been notably unsatisfactory. These occasional unpleasant conditions cause only passing comment by the

people, but the fact can not be ignored that standards of quality are rising. With the supplies of most of the large cities of the country made brilliant by filtration, the supplies of Greater Boston' will before long suffer by comparison. For many years, before the days of filtration, the water supplies of New England were of much better quality than those of the South and Middle West, but with the very rapid application of filtration to these naturally muddy waters the tables are being turned and the New England supplies, because of their color, sediment, turbidity, and occasional growths of odor-producing organisms, are coming to be of lower standard of attractiveness than the others. These comparisons are more obvious to travelers than to persons who reside continually in one place and become accustomed to their own water supply.

It must not be forgotten also that while the surface water supplies of Massachusetts are well safeguarded against constant pollution, any unfiltered supply is subject to accidental contamination. Heavy rains may suddenly wash polluting substances into the streams. The "turn-over" of a reservoir, because of the disturbance of thermal stratification, may carry deposits from the bottom to the supply pipes of the city. There may be accidental infection resulting from the practices of boating, fishing, and ice-cutting. Storage in large reservoirs gives a high average factor of safety but may be subject to such irregularity that the chance of danger is one which should not be ignored. Almost every year, especially in the early spring, some city of the state suffers from the sudden occurrences of a mild type of dysentery, which is so general in its distribution that the public water supply would seem to be the only possible cause. These mild outbreaks seldom result in deaths, and the cases are not even reported. They come to the attention of the health officers informally, often through the press. They are usually of such short duration that by the time the epidemiologist and the sanitary engineer take up the study the bad conditions have passed. Whether these dysentery outbreaks have been caused by water and, if so, whether they have been due to such an organism as *B. Welchii*, whether to a recent infection, or to the accumulated sediment on reservoir bottoms is not known, but, if due to water, filtration will protect a community from them, provided the filtered water is not stored in an open reservoir.

In my opinion, the time is not far distant when the people will demand the filtration of all surface water supplies, and New England water-works superintendents will do well to keep this possibility in mind.

If filtration is to become general, the type of filter is a matter of importance and one which should already be receiving attention. Unfortunately, the satisfactory removal of color from soft water is one of the most difficult problems of water purification. The exact nature of the reaction between alum and coloring matter is not yet known. Sanitary chemists used to say that all of the aluminum sulphate was changed to hydrate and that none of it went through the filter. Mr. Hiram F. Mills

stoutly denied that this was so, — although he could give no reason for it, — and we are now coming to believe that he was right. The use of alum with short periods of coagulation and mechanical filtration of the ordinary type is, in my opinion, inappropriate to our soft-colored Massachusetts surface waters. We must find some modification of the process which will be better, and I think this can be found. The corrosion problem in our state is serious already and must not be made more so by inappropriate chemical treatment. This is no place to enter upon a discussion of this problem, but it is one for the State Department of Public Health and for this Association to study in all seriousness.

Use of Water Analyses.

Finally, the writer wishes to urge the water-works superintendents of New England to give greater attention to the analyses of the water supplies under their charge. Analyses are useless unless used. The state sanitary engineers and chemists use them constantly in the course of their supervision, but even this tends to become a perfunctory proceeding unless the superintendents show a coöperative interest. In 1917 the Health Commissioner of Massachusetts sent out a questionnaire relating to water analyses. In reply, thirty-two superintendents said they made no use of the analyses sent out by the State Department of Health; 19 said that they kept them on file; 18 said that they published them in their annual report; 23 said that they occasionally showed them to inquiring consumers; 28 said that they used them to compare present with past conditions; and only four said that they regarded them as having any important use. The following extracts from the replies illustrate the different points of view:

"I have not read a copy of the analyses for a year or more."

"About once a year some one asks to see them."

"It is good to be able to say we have the water frequently analysed."

"Enables us to give intelligent answers to inquiries regarding water supplies"

"If any water-taker growls about the water, I just show him the last report, and that seems to settle the matter."

"Very valuable."

"No use, except to know that the State Department is keeping tabs on us."

"Value for reference and comparison year by year."

"To show to inquiring strangers."

"To show to federal inspectors."

"Have relied upon analyses for record of purity."

"Only to show to disgruntled water-takers."

"To watch the need of cleaning reservoir."

"I regard them as of the highest value."

"To determine whether there is unusual pollution."

"Analyses make us feel sure that the water is all right."

"To determine increase in pollution."
"Guidance in protecting the supply."
"To look out for turbidity and nitrates."
"To tell whether our suction pipe is tight."
"Essential to watch chlorine."
"The fact that the State Department of Health makes analyses seems to be sufficient to satisfy our consumers that there is no danger."
"Requested by doctors in interest of patients."

All of the consulting engineers who replied to the questionnaire were emphatic in their appreciation of the analytical work being done.

The results of this canvass must be regarded as a serious reflection on the present system of analysis and also on the interest which the local authorities take in the attractiveness of the water which they supply. They show an over-confidence in state supervision. Since the active work of Mills, Stearns, Drown, and Sedgwick, a new generation of superintendents has come forward, and it is because the men of the present day need to have their interest aroused that the writer has brought together various facts and ideas which, for the most part, are not new and which are already well known to many of the members of this Association. It is hoped also that the State Department of Public Health will revise its present system in order to bring it into line with the analytical standards generally adopted elsewhere in the United States and in order to make the data of greater practical value to the water superintendents.

TABLE 1

List of Cities and Towns im Massachusetts which have Public Water Supplies, January 1, 1920.

SURFACE WATER

Abington
Acushnet
Agawam
Amherst
Andover
Arlington (Metropolitan)
Ashburnham
Ashfield
Athol
Belmont (Metropolitan)
Beverly
Blackstone
Blandford
Boston (Metropolitan)
Braintree
Brockton
Cambridge
Chelsea (Metropolitan)
Cheshire
Chester
Clinton
Colrain
Concord
Dalton
Danvers
East Longmeadow
Egremont
Erving
Everett (Metropolitan)
Fall River
Falmouth
Fitchburg
Gloucester
Great Barrington
Groveland
Hadley
Hatfield
Haverhill
Hinsdale
Holbrook
Holden
Holyoke
Hudson
Ipswich
Lancaster
Lawrence
Lee
Lenox
Leominster
Lexington (Metropolitan)
Lincoln
Longmeadow
Ludlow
Lynn
Malden (Metropolitan)
Marlborough
Maynard
Medford (Metropolitan)
Melrose (Metropolitan)
Middleton
Milton (Metropolitan)
Montague
Monterey
Nahant (Metropolitan)
New Bedford
North Andover
North Brookfield
Northampton
Northborough
Peabody
Pittsfield
Plymouth
Quincy (Metropolitan)
Randolph
Revere (Metropolitan)
Rockland
Rockport
Russell
Rutland
Salem
Saugus
Shelburne
Somerville (Metropolitan)
Southbridge
Spencer
Springfield
Stockbridge
Stoneham (Metropolitan)
Sunderland
Swampscott (Metropolitan)
Taunton
Wakefield
Watertown (Metropolitan)
Wayland
West Bridgewater
West Springfield
Westfield
Weymouth
Whitman
Williamsburg
Winchester
Winthrop (Metropolitan)
Worcester

GROUND WATER

Acton
Amesbury
Ashland
Attleborough
Avon
Ayer
Barnstable
Bedford
Billerica
Bridgewater
Brookline
Canton
Chelmsford (Centre & North)
Cohasset
Cummington
Dedham
Douglas
Dracut (including Collinsville
Dudley
Dunstable
Duxbury
Easthampton
Edgartown
Fairhaven
Foxborough
Franklin
Grafton
Granville
Groton
Hardwick
Holliston
Hopkinton

GROUND WATER — *Continued.*

Kingston	Needham	Tisbury
Littleton	Newton	Uxbridge
Lowell	North Attleborough	Walpole
Mansfield	Northbridge	Waltham
Marion	Norton	Ware
Marshfield	Oak Bluffs	Webster
Mattapoisett	Oxford	Wellesley
Medfield	Pepperell	West Brookfield
Medway	Plainville	West Stockbridge
Merrimac	Provincetown	Westborough
Methuen	Reading	Westford
Middleborough	Salisbury	Weston
Millbury	Sharon	Westwood*
Millis	Sheffield	Winchendon
Monson	Shirley	Woburn
Natick	Shrewsbury	Wrentham

BOTH SURFACE AND GROUND WATER

Adams	Hingham	Norwood
Barre	Hopedale	Orange
Brookfield (Centre and East)	Hull	Palmer (including Bondsville)
Chicopee	Huntington	Scituate
Dartmouth	Leicester	South Hadley
Deerfield (Centre and South)	Manchester	Southampton*
East Bridgewater	Marblehead	Stoughton
Easton	Milford	Wareham (including Onset)
Framingham	Nantucket	Westhampton*
Gardner	Newburyport	Williamstown
Gill	North Adams	Worthington
Greenfield	Northfield	

TABLE 1A

Cities and Towns which have Water Supplies in Common

Abington and Rockland	Milford and Hopedale
Brockton and Whitman	Montague and Erving
Brockton and East Bridgewater	New Bedford and Acushnet
Brockton and West Bridgewater	New Bedford and Dartmouth
Bridgewater and East Bridgewater	Randolph and Braintree
Blackstone and Woonsocket, R.I.	Randolph and Holbrook
Clinton and Lancaster	Rutland and Holden
Concord and Lincoln	Salem and Beverly
Danvers and Middleton	Springfield and East Longmeadow
Hingham and Hull	Springfield and Ludlow
Lynn and Saugus	

Metropolitan Water Supply

Arlington	Chelsea	Malden	Milton	Revere	Swampscott
Belmont	Everett	Medford	Nahant	Somerville	Watertown
Boston	Lexington	Melrose	Quincy	Stoneham	Winthrop

* Public supplies owned by private parties not listed in report of State Department of Public Health.

TABLE 2.

PUBLIC WATER SUPPLIES OF MASSACHUSETTS.

SEDIMENT AND ODOR.

Expressed as Per Cent. of Number of Samples,
1910–1919.

City or Town.	Sediment: None.	Sediment: Very Slight.	Sediment: Slight.	Sediment: Considerable.	Sediment: High	Odor: None.	Odor: Very Faint	Odor: Faint.	Odor: Distinct.	Odor: Decided and Strong
Abington	28.0	54.0	16.0	2.0	0.0	2.0	24.0	50.0	22.0	2.0
Acton	74.0	16.7	9.3	0.0	0.0	98.2	1.8	0.0	0.0	0.0
Acushnet	9.3	74.0	15.5	1.2	0.0	0.0	2.5	36.0	47.8	13.7
Adams	38.0	55.7	5.0	1.3	0.0	28.9	35.0	27.8	8.3	0.0
Agawam	28.1	44.2	21.5	6.2	0.0	23.6	14.7	32.6	25.4	3.7
Amesbury	8.0	34.7	28.0	29.3	0.0	85.4	9.3	4.0	1.3	0.0
Amherst	2.8	63.3	26.6	7.3	0.0	0.9	12.8	42.2	39.5	4.6
Andover	21.2	69.0	9.8	0.0	0.0	3.3	14.7	47.5	31.2	3.3
Arlington	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Ashburnham	39.6	51.0	5.6	3.8	0.0	24.7	37.7	35.8	1.8	0.0
Ashfield	58.0	35.5	6.5	0.0	0.0	3.2	19.4	51.6	25.8	0.0
Ashland	60.7	19.7	16.1	3.5	0.0	94.7	0.0	5.3	0.0	0.0
Athol	11.3	52.2	23.9	12.6	0.0	9.5	14.9	33.3	32.6	9.7
Attleborough	93.0	1.8	1.7	3.5	0.0	94.6	1.8	1.8	1.8	0.0
Avon	81.0	16.7	0.0	2.3	0.0	100.0	0.0	0.0	0.0	0.0
Ayer	58.2	32.9	8.9	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Barnstable	92.3	7.7	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Barre	2.0	45.1	39.2	13.7	0.0	2.0	17.6	53.0	21.6	5.8
Bedford	59.0	37.2	3.8	0.0	0.0	84.7	11.5	3.8	0.0	0.0
Belmont	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Beverly	15.1	26.6	40.4	17.3	0.6	6.2	15.5	18.2	40.9	19.0
Billerica	8.2	50.0	36.0	5.8	0.0	97.7	2.3	0.0	0.0	0.2
Blackstone*	...	...	...	...	...	...	...	...	...	...
Blandford	57.3	34.6	6.1	2.0	0.0	26.6	38.8	32.6	2.0	0.0
Boston	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Braintree	59.6	36.2	4.2	0.0	0.0	87.3	4.3	6.3	2.1	0.0
Bridgewater	57.6	30.4	9.8	2.2	0.0	94.5	3.3	1.1	1.1	0.0
Brockton	3.7	59.5	32.5	4.3	0.0	11.1	46.0	31.9	11.0	0.0
Brookfield	84.4	12.8	0.0	2.8	0.0	95.8	0.0	2.8	0.0	1.4
Brookline	63.0	32.2	4.8	0.0	0.0	95.2	3.7	1.1	0.0	0.0
Cambridge	1.8	46.2	43.0	9.0	0.0	0.0	0.7	30.8	58.7	9.8
Canton	86.3	9.4	3.2	1.1	0.0	97.9	1.0	1.1	0.0	0.0
Chelmsford	78.5	20.6	0.0	0.9	0.0	92.5	5.6	1.9	0.0	0.0
Chelsea	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Cheshire	11.8	78.5	7.8	1.9	0.0	17.6	51.0	25.5	5.9	0.0
Chester	5.0	95.0	0.0	0.0	0.0	5.0	20.0	70.0	5.0	0.0
Chicopee	21.6	51.2	25.3	1.9	0.0	41.4	12.9	30.3	14.8	0.6
Clinton	4.5	64.4	31.1	0.0	0.0	0.0	18.9	60.0	21.1	0.0
Cohasset	41.3	28.2	20.6	9.9	0.0	58.2	24.3	13.5	4.0	0.0
Colrain	30.0	70.0	0.0	0.0	0.0	23.3	40.0	33.4	3.3	0.0
Concord	26.4	56.6	9.4	7.6	0.0	5.7	35.9	49.0	9.4	0.0
Cummington*	...	...	...	...	...	...	...	...	...	...
Dalton	9.8	82.0	8.2	0.0	0.0	0.0	27.8	41.0	31.2	0.0
Danvers	10.0	78.3	11.7	0.0	0.0	0.0	15.0	30.0	46.7	8.3
Dartmouth	9.3	74.0	15.5	1.2	0.0	0.0	2.5	36.0	47.8	13.7
Dedham	98.0	2.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Deerfield	61.3	33.9	4.8	0.0	0.0	29.0	37.2	30.6	3.2	0.0
Douglas	38.8	47.8	11.9	1.5	0.0	100.0	0.0	0.0	0.0	0.0
Dracut	67.0	25.9	5.3	1.8	0.0	96.4	1.8	1.8	0.0	0.0
Dudley	88.5	11.5	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Dunstable*	...	...	...	...	...	...	...	...	...	...
Duxbury	96.8	3.2	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0

TABLE 2. — *Continued.*

City or Town	Sediment.					Odor.				
	None.	Very Slight.	Slight.	Considerable.	High	None.	Very Faint.	Faint.	Distinct	Decided and Strong
E. Bridgewater	23.0	49.2	24.3	3.5	0.0	41.2	30.6	20.8	7.4	0.0
Easthampton	82.4	13.2	4.1	0.0	0.0	100.0	0.0	0.0	0.0	0.0
E. Longmeadow	28.1	44.7	21.1	6.1	0.0	23.6	14.6	32.6	25.7	3.5
Easton	98.0	2.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Edgartown	90.0	10.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Egremont	57.8	38.4	3.8	0.0	0.0	23.0	16.2	30.8	0.0	0.0
Erving	34.6	16.2	17.3	1.9	0.0	13.5	28.8	40.4	17.3	0.0
Everett	7.1	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Fairhaven	87.5	10.4	2.1	0.0	0.0	66.6	20.9	6.2	4.2	2.1
Fall River	0.8	53.0	42.0	1.2	0.0	0.0	7.6	64.7	25.2	2.5
Falmouth	16.6	79.7	3.7	0.0	0.0	7.4	35.2	46.3	7.4	3.7
Fitchburg	7.2	51.7	33.5	7.2	0.4	1.7	9.3	53.0	34.4	1.6
Foxborough	93.1	6.9	0.0	0.0	0.0	96.5	0.0	3.5	0.0	0.0
Framingham	65.5	29.6	4.9	0.0	0.0	93.7	3.5	2.1	0.7	0.0
Franklin	93.0	5.6	1.4	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Gardner	11.2	74.2	13.5	1.1	0.0	1.7	17.4	38.2	33.7	9.0
Gill*	...	...	...	...	...	...	...	...	...	...
Gloucester	7.8	70.5	21.7	0.0	0.0	0.0	4.5	43.0	47.5	5.0
Grafton	72.2	25.0	2.8	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Granville	87.8	12.2	0.0	0.0	0.0	84.9	15.1	0.0	0.0	0.0
Great Barrington	15.6	55.5	22.6	6.3	0.0	10.9	37.5	39.1	10.9	1.6
Greenfield	8.5	73.2	12.2	6.1	0.0	3.6	46.3	39.0	1.1	0.0
Groton	96.0	4.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Groveland*	...	...	...	...	...	...	...	...	...	...
Hadley	24.4	64.5	11.1	0.0	0.0	4.5	24.4	62.2	8.9	0.0
Hardwick*	...	...	...	...	...	...	...	...	...	...
Hatfield	28.6	65.3	4.1	2.0	0.0	6.1	26.6	55.0	12.3	0.0
Haverhill	12.6	65.3	19.9	2.2	0.0	0.5	9.5	48.5	37.0	1.5
Hingham	23.8	61.0	11.3	3.9	0.0	18.8	13.4	33.6	26.8	7.4
Hinsdale	22.2	66.7	7.4	3.7	0.0	11.1	18.5	44.5	22.2	3.7
Holbrook	59.6	36.2	4.2	0.0	0.0	87.3	4.3	6.3	2.1	0.0
Holden	41.5	54.7	3.8	0.0	0.0	1.9	39.6	45.5	13.0	0.0
Holliston	8.0	56.0	36.0	0.0	0.0	28.0	16.0	20.0	36.0	0.0
Holyoke	5.5	55.8	35.5	3.2	0.0	0.2	11.1	55.3	31.2	2.2
Hopedale	63.6	36.4	0.0	0.0	0.0	85.0	9.0	1.5	1.5	0.0
Hopkinton	71.8	25.6	2.6	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Hudson	1.2	62.5	28.4	7.9	0.0	0.0	12.5	43.3	36.3	7.9
Hull	23.8	61.0	11.3	3.9	0.0	18.8	13.4	33.6	26.8	7.4
Huntington	57.2	38.0	4.8	0.0	0.0	19.0	23.8	52.5	4.7	0.0
Hyde Park†	52.5	23.3	19.2	5.0	0.0	72.5	19.8	7.7	0.0	0.0
Ipswich	0.0	52.7	17.3	0.0	0.0	0.0	4.0	13.3	18.7	4.0
Kingston	81.6	18.4	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Lancaster	4.4	64.5	31.1	0.0	0.0	0.0	18.9	60.0	21.1	0.0
Lawrence	20.8	51.5	21.9	2.8	0.0	0.0	84.2	15.8	0.0	0.0
Lee	16.8	76.5	1.5	2.2	0.0	1.1	21.4	57.3	20.2	0.0
Leicester	59.7	33.3	5.8	1.2	0.0	71.7	13.8	10.3	1.2	0.0
Lenox	14.3	61.9	17.5	6.3	0.0	6.4	11.5	36.5	11.1	1.5
Leominster	0.4	31.7	45.0	19.5	0.1	0.8	11.9	49.2	34.3	3.8
Lexington	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Lincoln	16.7	66.7	13.3	3.3	0.0	11.7	25.0	43.3	18.3	1.7
Littleton	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Longmeadow	26.5	46.0	21.6	5.9	0.0	22.1	15.2	33.6	25.5	3.6
Lowell	7.7	28.9	35.8	27.6	0.0	67.3	26.7	5.6	0.4	0.0
Ludlow	28.1	44.7	21.0	6.2	0.0	23.6	14.3	32.6	25.8	3.7
Lynn	1.0	56.7	37.8	4.5	0.0	0.0	1.7	30.0	56.8	11.5

* No figures. † Hyde Park for years 1910–1911

TABLE 2. — *Continued.*

City or Town.	Sediment.					Odor.				
	None.	Very Slight.	Slight.	Considerable.	High.	None.	Very Faint.	Faint.	Distinct.	Decided and Strong.
Malden	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Manchester	15.8	69.1	13.2	1.9	0.0	34.7	8.0	26.0	20.0	11.3
Mansfield	96.4	3.6	0.0	0.0	0.0	98.2	0.0	1.8	0.0	0.0
Marblehead	56.3	17.8	5.2	20.0	0.7	88.2	8.1	3.7	0.0	0.0
Marion	91.7	4.2	1.1	0.0	0.0	98.9	0.0	1.1	0.0	0.0
Marlborough	4.9	53.1	37.8	4.2	0.0	0.0	7.7	44.7	42.7	4.9
Marshfield	88.2	11.8	0.0	0.0	0.0	88.2	11.8	0.0	0.0	0.0
Mattapoisett	83.0	7.7	1.5	7.8	0.0	97.0	3.0	0.0	0.0	0.0
Maynard	17.6	73.6	5.9	2.9	0.0	0.0	17.6	56.0	26.4	0.0
Medfield	17.3	79.3	3.4	0.0	0.0	89.7	6.9	3.4	0.0	0.0
Medford	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Medway	79.2	12.5	8.3	0.0	0.0	100 0	0.0	0.0	0.0	0.0
Melrose	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Merrimac	86.2	9.8	4.0	0.0	0.0	98.0	0.0	2.0	0.0	0.0
Methuen	9.6	68.4	18.2	3.8	0.0	81.8	14.4	2.9	0.9	0.0
Middleborough	27.0	9.9	20.4	38.8	3.9	82.3	15.1	1.9	0.7	0.0
Middleton	10.0	78.3	11.7	0.0	0.0	0.0	15.0	30.0	46.7	8.3
Milford	63.6	36.4	0.0	0.0	0.0	85.0	9.0	4.5	1.5	0.0
Millbury	79.5	16.4	4.1	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Millis	92.6	7.4	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Milton	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Monson	73.8	26.2	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Montague	34.6	46.2	17.3	1.9	0.0	13.5	28.8	40.4	17.3	0.0
Monterey*	...	...	...	...	...	...	...	...	...	...
Nahant	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.0
Nantucket	12.5	39.8	39.8	7.9	0.0	26.2	6.8	36.3	28.4	2.3
Natick	98.0	2.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Needham	88.5	11.5	0.0	0.0	0.0	99.3	0.0	0.7	0.0	0.0
New Bedford	9.3	74.0	15.5	1.2	0.0	0.0	2.5	36.0	47.8	13.7
Newburyport	16.8	49.5	27.2	6.5	0.0	64.0	7.0	10.9	13.0	5.1
Newton	51.6	37.5	10.9	0.0	0.0	95.3	1.5	1.6	1.6	0.0
North Adams	9.8	69.8	15.5	4.9	0.0	8.5	38.8	44.3	8.4	0.0
Northampton	5.0	59.2	33.3	2.5	0.0	0.0	19.2	41.7	35.8	3.3
North Andover	5.2	74.6	21.1	0.0	0.0	1.8	8.9	48.2	35.7	5.4
N. Attleborough	74.0	16.7	9.3	0.0	0.0	98.0	2.0	0.0	0.0	0.0
Northborough	3.3	37.3	49.2	10.2	0.0	0.0	1.6	18.7	61.0	18.7
Northbridge	22.0	49.2	20.4	8.4	0.0	10.2	23.8	44.0	13.5	8.5
N. Brookfield	1.4	25.4	55.3	17.9	0.0	0.0	2.9	31.4	62.7	3.0
Northfield	78.3	21.7	0.0	0.0	0.0	0.0	34.8	56.5	8.7	0.0
Norton	93.0	4.7	2.3	0.0	0.0	97.7	0.0	2.3	0.0	0.0
Norwood	14.3	44.0	34.5	7.2	0.0	49.0	6.6	21.0	21.6	1.8
Oak Bluffs	66.0	34.0	0.0	0.0	0.0	98.0	2.0	0.0	0.0	0.0
Orange	30.3	66.7	3.0	0.0	0.0	24.2	15.3	54.0	6.0	0.0
Oxford	91.0	6.0	0.0	0.0	0.0	100.0	0.0	0 0	0.0	0.0
Palmer	35.5	36.4	25.6	2.5	0.0	58.6	0.8	23.2	14.1	3.3
Peabody	3.9	55.8	39.0	1.3	0.0	1.9	9.1	44.8	39.0	5.2
Pepperell	95.5	3.0	1.5	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Pittsfield	10.6	68.0	18.7	2.7	0.0	0.3	20.2	40.2	33.0	6.3
Plainville	47.8	13.3	22.2	16.7	0.0	96.7	2.2	0.0	1.1	0.0
Plymouth	4.1	69.7	26.2	0.0	0.0	10.7	45.1	33.6	9.8	0.8
Provincetown	95.5	4.5	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Quincy	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Randolph	11.7	80.0	8.3	0.0	0.0	0.0	6.7	35.0	53.3	5.0
Reading	36.5	11.3	5 7	44.6	1.9	54.1	23.2	17.0	5.7	0.0
Revere	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Rockland	28.0	54.0	16.0	2.0	0.0	2.0	24.0	50.0	22.0	2.0

TABLE 2. — *Continued.*

City or Town.	Sediment. None.	Sediment. Very Slight.	Sediment. Slight.	Sediment. Considerable.	Sediment. High.	Odor. None.	Odor. Very Faint.	Odor. Faint.	Odor. Distinct	Odor. Decided and Strong
Rockport	0.0	28.3	50.0	21.7	0.0	0.0	1.7	25.0	53.3	20.0
Russell	61.8	31.0	3.6	3.6	0.0	5.5	21.8	56.3	10.9	5.5
Rutland	41.5	54.7	3.8	0.0	0.0	1.9	39.6	45.5	13.0	0.0
Salem	15.1	26.6	40.4	17.3	0.6	6.2	15.5	18.2	40.9	19.2
Salisbury	50.0	46.2	3.8	0.0	0.0	61.5	15.4	23.1	0.0	0.0
Saugus	1.0	56.7	37.8	4.5	0.0	0.0	1.7	30.0	56.8	11.5
Scituate	69.3	22.6	8.1	0.0	0.0	80.7	8.1	4.8	4.8	1.6
Sharon	91.0	5.1	3.9	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Sheffield	60.0	40.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Shelburne	67.6	32.4	0.0	0.0	0.0	38.3	26.5	26.4	8.8	0.0
Shirley	86.8	11.3	1.9	0.0	0.0	98.1	1.9	0.0	0.0	0.0
Shrewsbury	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Somerville	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
South Hadley	25.4	33.3	33.3	8.0	0.0	24.4	10.4	36.3	24.4	4.5
Southampton*	...	...	...	...	...	...	...	...	...	...
Southbridge	9.2	51.7	35.0	4.1	0.0	0.0	11.6	48.4	38.6	1.4
Spencer	58.3	39.0	2.7	0.0	0.0	5.5	19.5	55.5	19.5	0.0
Springfield	28.1	44.7	21.0	6.2	0.0	23.6	14.3	32.6	25.8	3.7
Stockbridge	20.9	61.4	17.7	0.0	0.0	0.0	19.3	32.3	43.6	4.8
Stoneham	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Stoughton	34.2	63.2	2.6	0.0	0.0	18.6	23.6	36.8	21.0	0.0
Sunderland*	...	...	...	...	...	...	...	...	...	...
Swampscott	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Taunton	5.6	77.5	16.9	0.0	0.0	0.8	12.9	46.8	37.1	2.4
Tisbury	80.5	13.0	6.5	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Uxbridge	88.2	11.8	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Wakefield	0.9	55.4	35.7	8.0	0.0	0.0	0.9	33.0	54.5	11.6
Walpole	75.0	25.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Waltham	56.9	33.9	7.9	1.3	0.0	98.8	0.8	0.4	0.0	0.0
Ware	98.1	1.9	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Wareham	66.7	31.8	1.5	0.0	0.0	64.4	14.3	18.2	3.1	0.0
Watertown	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Wayland	0.0	69.2	28.2	2.6	0.0	0.0	0.0	15.4	64.1	20.5
Webster	51.0	34.1	14.9	0.0	0.0	97.9	2.1	0.0	0.0	0.0
Wellesley	79.5	20.5	0.0	0.0	0.0	99.3	0.7	0.0	0.0	0.0
Westborough	13.2	77.3	9.5	0.0	0.0	3.8	22.6	66.1	7.5	0.0
W. Bridgewater	3.7	59.5	32.5	4.3	0.0	11.0	16.0	31.9	41.1	0.0
W. Brookfield	100.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Westfield	12.4	50.4	31.0	6.2	0.0	1.7	15.0	39.9	38.1	5.3
Westford	98.5	1.5	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Westhampton*	...	...	...	...	...	...	...	...	...	...
Weston	83.6	16.4	0.0	0.0	0.0	96.4	0.0	3.6	0.0	0.0
W. Springfield	56.1	34.1	9.8	0.0	0.0	80.2	14.5	4.0	1.3	0.0
W. Stockbridge*	...	...	...	...	...	...	...	...	...	...
Westwood*	...	...	...	...	...	...	...	...	...	...
Weymouth	11.5	67.3	21.2	0.0	0.0	0.0	7.7	32.7	50.0	9.6
Whitman	3.7	59.5	32.5	4.3	0.0	11.1	16.0	31.9	41.0	0.0
Williamsburg	6.2	73.0	20.8	0.0	0.0	2.1	33.2	48.0	16.7	0.0
Williamstown	25.7	65.7	5.7	2.9	0.0	20.0	31.4	37.2	11.4	0.0
Winchendon	38.0	25.0	22.0	15.0	0.0	87.0	10.0	2.0	1.0	0.0
Winchester	2.0	63.9	31.1	3.0	0.0	0.0	8.2	52.3	36.5	3.0
Winthrop	7.4	72.7	18.7	1.2	0.0	1.3	20.2	57.3	20.5	0.7
Woburn	99.0	1.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0
Worcester	4.2	61.2	29.6	5.0	0.0	0.2	9.1	56.4	32.7	1.6
Worthington	50.0	42.5	5.0	2.5	0.0	75.0	12.5	10.0	2.5	0.0
Wrentham	92.3	7.7	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0

* No figures.

TABLE 3.

Public Water Supplies of Massachusetts.

AVERAGE COLOR.

1910–1919.

City or Town.	Color.	City or Town.	Color.	City or Town.	Color.
Acton	0	Attleborough	4	Barre	15
Avon	0	Bedford	4	Billerica	15
Barnstable	0	Deerfield	4	Clinton	15
Brookfield (East)	0	Dracut	4	Lancaster	15
Duxbury	0	Monson	4	Williamsburg	15
Dudley	0	Williamstown	4	Fall River	16
Easthampton	0	Worthington	4	North Andover	16
Easton	0	Dedham	5	Braintree	17
Edgartown	0	Greenfield	5	Holbrook	17
Foxborough	0	Shelburne	5	Northbridge	17
Franklin	0	Ashburnham	6	Amesbury	18
Groton	0	Bridgewater	6	Hyde Park*	18
Hopkinton	0	Canton	6	Northampton	18
Kingston	0	Colrain	6	Norwood	18
Littleton	0	Concord	6	Taunton	19
Mansfield	0	Erving	6	Worcester	19
Marion	0	Grafton	6	Leominster	20
Marshfield	0	Holden	6	Maynard	20
Mattapoisett	0	Lincoln	6	Russell	20
Medfield	0	Manchester	6	Hinsdale	21
Millis	0	Montague	6	Holyoke	21
Natick	0	Rutland	6	Hopedale	21
Norton	0	Waltham	6	Milford	21
Oak Bluffs	0	Adams	7	Northfield	21
Oxford	0	Blandford	7	Wakefield	21
Pepperell	0	Lenox	7	Middleborough	22
Scituate	0	Spencer	7	Fitchburg	24
Sheffield	0	Woburn	7	Hingham	24
Shirley	0	East Bridgewater	8	Hull	24
Shrewsbury	0	Great Barrington	8	Peabody	24
Uxbridge	0	Abington	9	Stoughton	24
Walpole	0	Gardner	9	Haverhill	26
Ware	0	Hadley	9	Metropolitan District	
Wellesley	0	Hudson	9	Arlington	26
West Brookfield	0	Huntington	9	Belmont	26
Westford	0	North Adams	9	Boston	26
Wrentham	0	Rockland	9	Chelsea	26
Ashland	1	Brockton	10	Everett	26
Ayer	1	Chester	10	Lexington	26
Cheshire	1	Leicester	10	Malden	26
Douglas	1	Nantucket	10	Medford	26
Falmouth	1	Orange	10	Melrose	26
Granville	1	South Hadley	10	Milton	26
Medway	1	West Bridgewater	10	Nahant	26
Merrimac	1	Whitman	10	Quincy	26
Needham	1	Winchendon	10	Revere	26
North Attleborough	1	Longmeadow	11	Somerville	26
Provincetown	1	West Springfield	11	Stoneham	26
Sharon	1	Hatfield	12	Swampscott	26
Tisbury	1	Newburyport	12	Watertown	25
Wareham	1	Palmer	12	Winthrop	26
Egremont	2	Winchester	12	Pittsfield	26
Millbury	2	Brookline	13	Southbridge	26
Newton	2	Chelmsford (North)	13	Chicopee	27
Plymouth	2	Marblehead	13	Dalton	27
Webster	2	Stockbridge	13	Ipswich	28
Framingham	3	Weston	13	Agawam	29
Plainville	3	Andover	14	East Longmeadow	29
Westborough	3	Salisbury	14	Lee	29

TABLE 3. — *Continued.*

City or Town.	Color.	City or Town.	Color.	City or Town.	Color.
Lowell	29	Fairhaven	42	Wayland	85
Ludlow	29	Cambridge	43	Blackstone	*
Marlborough	29	Lynn	46	Cummington	*
Methuen	29	Saugus	46	Dunstable	*
Springfield	29	North Brookfield	47	Gill	*
Westfield	29	Reading	49	Groveland	*
Ashfield	30	Holliston	50	Hardwick	*
Lawrence	31	Danvers	52	Monterey	*
Amherst	32	Middleton	52	Southampton	*
Rockport	32	Athol	59	Sunderland	*
Acushnet	39	Northborough	61	West Stockbridge	*
Dartmouth	39	Cohasset	63	Westhampton	*
Gloucester	39	Weymouth	65	Westwood	*
New Bedford	39	Beverly	72		
Randolph	41	Salem	72		

* No figures available.

TABLE 4.

PUBLIC WATER SUPPLIES OF MASSACHUSETTS.

AVERAGE CHLORINE.

Parts per Million.

1910–1919.

City or Town.	Chlorine.	City or Town.	Chlorine.	City or Town.	Chlorine.
Sheffield	0.9	Montague	1.7	Gardner	3.1
Hinsdale	1.0	Springfield	1.7	Holden	3.2
North Adams	1.0	Amherst	1.8	Northborough	3.2
Williamstown	1.0	Athol	1.8	Rutland	3.2
Dalton	1.1	Holyoke	1.8	South Hadley	3.3
Lenox	1.1	Westford	1.8	Oxford	3.4
Shelburne	1.1	Chicopee	1.9	Concord	3.5
Worthington	1.1	Monson	1.9	Leicester	3.5
Adams	1.2	North Brookfield	1.9	Webster	3.5
Cheshire	1.2	Palmer	1.9	Plainville	3.6
Egremont	1.2	Blandford	2.0	Wrentham	3.6
Lee	1.2	Hadley	2.0	Bedford	3.7
Pittsfield	1.2	Hatfield	2.0	Hopedale	3.7
Stockbridge	1.2	Pepperell	2.0	Metropolitan District	
Ashfield	1.3	Ashburnham	2.1	Arlington	3.7
Great Barrington	1.3	Fitchburg	2.1	Belmont	3.7
Chester	1.4	Leominster	2.1	Boston	3.7
Northfield	1.4	Southbridge	2.1	Chelsea	3.7
Orange	1.4	Spencer	2.1	Everett	3.7
Colrain	1.5	Barre	2.2	Lexington	3.7
Deerfield	1.5	Groton	2.2	Malden	3.7
Granville	1.5	Longmeadow	2.2	Medford	3.7
Northampton	1.5	Brookfield (East)	2.3	Melrose	3.7
Williamsburg	1.5	Clinton	2.3	Milton	3.7
Winchendon	1.5	Lancaster	2.3	Nahant	3.7
Easthampton	1.6	Littleton	2.4	Quincy	3.7
Huntington	1.6	Dudley	2.5	Revere	3.7
Russell	1.6	Northbridge	2.5	Somerville	3.7
Westfield	1.6	West Springfield	2.5	Stoneham	3.7
Agawam	1.7	Worcester	2.6	Swampscott	3.7
East Longmeadow	1.7	Hudson	2.7	Watertown	3.7
Erving	1.7	West Brookfield	2.7	Winthrop	3.7
Greenfield	1.7	Westborough	2.9	Milford	3.7
Ludlow	1.7	Maynard	3.0	Millbury	3.7

TABLE 4 — *Continued.*

City or Town.	Chlorine.	City or Town.	Chlorine.	City or Town.	Chlorine.
Douglas	3.8	Dartmouth	5.8	Tisbury	9.7
Lincoln	3.8	Medway	5.8	Oak Bluffs	9.8
Wayland	3.8	New Bedford	5.8	Beverly	9.9
Andover	3.9	Plymouth	5.8	Salem	9.9
Ashland	3.9	Norwood	5.9	Falmouth	10.1
Norton	3.9	Acton	6.0	Dedham	10.5
Holliston	4.0	Easton	6.0	Sharon	10.5
Shirley	4.0	Salisbury	6.0	Fairhaven	10.6
Stoughton	4.0	Bridgewater	6.3	Barnstable	11.6
Danvers	4.1	Brockton	6.4	Braintree	11.7
Middleton	4.1	East Bridgewater	6.4	Holbrook	11.7
Ware	4.1	Wareham	6.4	Hopkinton	11.8
Billerica	4.2	West Bridgewater	6.4	Wellesley	11.8
Medfield	4.2	Weston	6.4	Grafton	14.1
Walpole	4.4	Whitman	6.4	Manchester	14.2
Dracut	4.5	Fall River	6.5	Cohasset	15.7
Mansfield	4.5	Middleborough	6.7	Hyde Park*	18.1
Winchester	4.5	Randolph	6.9	Nantucket	21.8
Foxborough	4.6	Abington	7.2	Framingham	21.8
Haverhill	4.6	Marion	7.2	Reading	30.0
Methuen	4.6	Rockland	7.2	Scituate	34.2
Chelmsford (North)	4.7	Hingham	7.3	Rockport	49.9
Lawrence	4.7	Hull	7.3	Marblehead	50.5
North Andover	4.7	Needham	7.3	Provincetown	59.2
Canton	4.9	Kingston	7.5	Woburn	59.3
Lowell	4.9	Waltham	7.5	Marshfield	88.0
Franklin	5.1	Natick	7.6		
Marlborough	5.1	Millis	7.7	Blackstone	†
Ayer	5.2	Newburyport	7.7	Cummington	†
Newton	5.2	Lynn	7.8	Dunstable	†
Shrewsbury	5.2	Saugus	7.8	Gill	†
Attleborough	5.3	Brookline	7.9	Groveland	†
Merrimac	5.3	Ipswich	7.9	Hardwick	†
North Attleborough	5.4	Wakefield	8.2	Monterey	†
Avon	5.5	Duxbury	8.6	Southampton	†
Cambridge	5.5	Peabody	9.0	Sunderland	†
Weymouth	5.5	Edgartown	9.3	West Stockbridge	†
Taunton	5.6	Mattapoisett	9.3	Westhampton	†
Uxbridge	5.7	Amesbury	9.4	Westwood	†
Acushnet	5.8	Gloucester	9.7		

* Hyde Park for years 1910 and 1911. † No Figures.

TABLE 5.

PUBLIC WATER SUPPLIES OF MASSACHUSETTS.

AVERAGE HARDNESS.

Parts per Million.

1910–1919.

City or Town.	Hardness.	City or Town.	Hardness.	City or Town.	Hardness.
Edgartown	4	Barnstable	7	Montague	8
Falmouth	4	Brockton	7	Oak Bluffs	8
Gloucester	5	Brookfield (East)	7	Southbridge	8
Leominster	5	Fitchburg	7	Taunton	8
Wareham	5	Hinsdale	7	Weymouth	8
Duxbury	6	Maynard	7	Acushnet	9
Northbridge	6	Rockland	7	Dartmouth	9
Tisbury	6	West Bridgewater	7	New Bedford	9
Westfield	6	Whitman	7	North Brookfield	9
Abington	7	Amherst	8	Plymouth	9
Ashburnham	7	Erving	8	Fall River	10

TABLE 5 — *Continued.*

City or Town.	Hardness.	City or Town.	Hardness.	City or Town.	Hardness.
Holden	10	Bedford	16	Braintree	27
Orange	10	Blandford	16	Bridgewater	27
Rutland	10	Franklin	16	Holbrook	27
Spencer	10	Mansfield	16	Lowell	27
Stoughton	10	Medfield	16	Newton	27
Winchendon	10	Wayland	16	Norwood	27
Dudley	11	Westford	16	Billerica	28
Marion	11	Chester	17	Newburyport	28
Monson	11	Concord	17	Provincetown	28
Northfield	11	Douglas	17	Groton	29
South Hadley	11	East Bridgewater	17	Medway	29
Agawam	12	Easton	17	Deerfield	31
Athol	12	Lincoln	17	Methuen	31
Clinton	12	Norton	17	Weston	31
East Longmeadow	12	Sheffield	17	Greenfield	32
Kingston	12	Shrewsbury	17	Shelburne	32
Lancaster	12	Webster	17	Acton	35
Ludlow	12	Danvers	18	Sharon	35
Northborough	12	Hopedale	18	West Springfield	36
Shirley	12	Littleton	18	Waltham	37
Springfield	12	Marlborough	18	Millis	38
West Brookfield	12	Middleton	18	Brookline	39
Worthington	12	Milford	18	Dracut	39
Wrentham	12	North Andover	18	Easthampton	39
Ashland	13	Oxford	18	Colrain	40
Barre	13	Uxbridge	18	Dedham	41
Chicopee	13	Walpole	18	Pittsfield	42
Hingham	13	Chelmsford (North)	19	Salisbury	42
Hull	13	Hadley	19	Wellesley	42
Randolph	13	Huntington	19	North Adams	43
Worcester	13	Northampton	19	Grafton	45
Metropolitan District		Williamsburg	19	Natick	46
Arlington	14	Attleborough	20	Stockbridge	49
Belmont	14	Gardner	20	Woburn	49
Boston	14	Granville	20	Cohasset	50
Chelsea	14	Holyoke	20	Framingham	50
Everett	14	Ipswich	20	Hyde Park*	54
Lexington	14	Lee	20	Cheshire	55
Malden	14	Hatfield	21	Hopkinton	56
Medford	14	Wakefield	21	Adams	56
Melrose	14	Avon	22	Great Barrington	57
Milton	14	Mattapoisett	22	Lenox	58
Nahant	14	Millbury	22	Marshfield	58
Quincy	14	Peabody	22	Williamstown	64
Revere	14	Plainville	22	Haverhill	62
Somerville	14	Rockport	22	Reading	65
Stoneham	14	Lynn	23	Scituate	77
Swampscott	14	Saugus	23	Marblehead	79
Watertown	14	Ware	23	Amesbury	100
Winthrop	14	Beverly	24		
Foxborough	14	Leicester	24	Blackstone	†
Hudson	14	Needham	24	Cummington	†
Palmer	14	North Attleborough	24	Dunstable	†
Pepperell	14	Salem	24	Gill	†
Russell	14	Manchester	25	Groveland	†
Westborough	14	Middleborough	25	Hardwick	†
Andover	15	Ayer	26	Monterey	†
Canton	15	Cambridge	26	Southampton	†
Dalton	15	Egremont	26	Sunderland	†
Holliston	15	Fairhaven	26	West Stockbridge	†
Lawrence	15	Longmeadow	26	Westhampton	†
Nantucket	15	Merrimac	26	Westwood	†
Winchester	15	Ashfield	27		

* Hyde Park for years 1910 and 1912. † No figures available.

TABLE 6.

Public Water Supplies of Massachusetts.

AVERAGE IRON.

Parts per Million.

1910–1919.

City or Town.	Iron.	City or Town.	Iron.	City or Town.	Iron.
Mansfield	0.02	Granville	0.10	Spencer	0.15
Oxford	0.04	Hadley	0.10	Amherst	0.16
Dudley	0.05	Sharon	0.10	Cambridge	0.16
Edgartown	0.05	West Bridgewater	0.10	Canton	0.16
Littleton	0.05	Whitman	0.10	Hudson	0.16
Natick	0.05	Adams	0.11	Huntington	0.16
Pepperell	0.05	Clinton	0.11	Marblehead	0.16
Shirley	0.05	Fairhaven	0.11	Pittsfield	0.16
Ware	0.05	Fall River	0.11	Russell	0.16
Acton	0.06	Framingham	0.11	Shelburne	0.16
Brookfield (East)	0.06	Great Barrington	0.11	Stockbridge	0.16
Chester	0.06	Lancaster	0.11	Wellesley	0.16
Colrain	0.06	Lenox	0.11	Worcester	0.16
Duxbury	0.06	North Attleborough	0.11	Acushnet	0.17
Hatfield	0.06	Tisbury	0.11	Braintree	0.17
Marion	0.06	Ashburnham	0.12	Danvers	0.17
Mattapoisett	0.06	Ayer	0.12	Dartmouth	0.17
Millis	0.06	Greenfield	0.12	Haverhill	0.17
Scituate	0.06	Hopkinton	0.12	Holbrook	0.17
Shrewsbury	0.06	Lincoln	0.12	Longmeadow	0.17
West Brookfield	0.06	Orange	0.12	Middleton	0.17
Andover	0.07	Stoughton	0.12	New Bedford	0.17
Dedham	0.07	Westborough	0.12	Dracut	0.18
Easton	0.07	Dalton	0.13	Gardner	0.18
Medway	0.07	Merrimac	0.13	Ipswich	0.18
Monson	0.07	Provincetown	0.13	Ashfield	0.19
Needham	0.07	Taunton	0.13	Hopedale	0.19
Norton	0.07	Marshfield	0.14	Milford	0.19
Uxbridge	0.07	Millbury	0.14	Abington	0.20
Wareham	0.07	Northampton	0.14	Bedford	0.20
Westford	0.07	Webster	0.14	Rockland	0.20
Weston	0.07	Metropolitan District		Concord	0.21
Attleborough	0.08	Arlington	0.15	Peabody	0.21
Avon	0.08	Belmont	0.15	North Adams	0.22
Barnstable	0.08	Boston	0.15	Randolph	0.22
Easthampton	0.08	Chelsea	0.15	Williamsburg	0.22
Egremont	0.08	Everett	0.15	East Bridgewater	0.23
Groton	0.08	Lexington	0.15	North Andover	0.23
Medfield	0.08	Malden	0.15	Winchester	0.23
Newton	0.08	Medford	0.15	Erving	0.24
Oak Bluffs	0.08	Melrose	0.15	Montague	0.24
Sheffield	0.08	Milton	0.15	Plymouth	0.24
Woburn	0.08	Nahant	0.15	Westfield	0.24
Ashland	0.09	Quincy	0.15	Barre	0.25
Cheshire	0.09	Revere	0.15	Maynard	0.25
Falmouth	0.09	Somerville	0.15	West Springfield	0.25
Foxborough	0.09	Stoneham	0.15	Northbridge	0.26
Franklin	0.09	Swampscott	0.15	Wakefield	0.26
Holden	0.09	Watertown	0.15	Williamstown	0.26
Kingston	0.09	Winthrop	0.15	Leominster	0.27
Northfield	0.09	Brookline	0.15	Salisbury	0.27
Rutland	0.09	Grafton	0.15	South Hadley	0.27
Walpole	0.09	Hingham	0.15	Northborough	0.28
Wrentham	0.09	Hull	0.15	Holyoke	0.29
Blandford	0.10	Lee	0.15	Worthington	0.29
Brockton	0.10	Leicester	0.15	Weymouth	0.30
Deerfield	0.10	Manchester	0.15	Southbridge	0.31

TABLE 6 — *Continued.*

City or Town.	Iron.	City or Town.	Iron.	City or Town.	Iron.
Waltham	0.31	Wayland	0.38	Amesbury	1.34
Agawam	0.32	Hyde Park*	0.43	Middleborough	1.45
Athol	0.32	Douglas	0.45	Reading	1.72
Chelmsford (North)	0.32	Newburyport	0.48	Blackstone	†
East Longmeadow	0.32	Gloucester	0.52	Cummington	†
Ludlow	0.32	Cohasset	0.63	Dunstable	†
Lynn	0.32	Methuen	0.68	Gill	†
Saugus	0.32	Hinsdale	0.69	Groveland	†
Springfield	0.32	Billerica	0.71	Hardwick	†
Chicopee	0.33	North Brookfield	0.76	Monterey	†
Marlborough	0.33	Lawrence	0.85	Southampton	†
Plainville	0.33	Beverly	0.86	Sunderland	†
Bridgewater	0.36	Salem	0.86	West Stockbridge	†
Nantucket	0.36	Winchendon	0.88	Westhampton	†
Norwood	0.36	Rockport	0.90	Westwood	†
Fitchburg	0.38	Holliston	0.92		
Palmer	0.38	Lowell	0.96		

*Hyde Park for years 1910 and 1911.

† No figures available.

TABLE 7.

Corrosion Factors.

(Miscellaneous Data.)

City or Town.	Number of Observations.	Parts per Million. Free CO_2	Alkalinity.
Abington	6	1.6	5.2
Andover	5	1.3	11.4
Ashburnham	1	3.1	13.0
Boston	1	11.0	13.0
Braintree	3	1.4	9.6
Brookline	4	12.2	48.2
Brockton	5	1.7	8.1
Chicopee	2	3.4	9.2
Dracut	1	3.1	42.0
Fairhaven	1	21.7	12.0
Haverhill	12	1.4	16.8
Hingham	10	6.0	8.2
Ipswich	1	7.8	15.5
Kingston	1	20.3	11.5
Lawrence	7	4.2	12.3
Lincoln	1	5.5	3.0
Lowell	8	20.6	31.0
Marblehead	2	5.7	34.0
Marlborough	5	3.3	7.6
Methuen	1	2.9	28.0
Middleborough	1	41.4	17.5
Milford	1	15.2	10.5
Millbury	1	29.5	15.5
New Bedford	1	9.5	9.0
Newburyport	3	6.7	24.8
Newton	4	18.8	29.2
North Andover	5	1.4	14.0
North Easton	1	23.4	10.0
Norwood	11	8.1	8.3
Palmer	1	5.0	10.5
Provincetown	1	37.4	3.9
Reading	1	16.4	63.0
Revere	1	7.4	59.0
Sharon	1	15.1	27.0
South Hadley	2	6.0	8.7
Springfield	3	1.1	8.1
Stoughton	12	11.2	7.5
Wakefield	5	1.8	15.9
Waltham	3	29.3	37.3
Wellesley	1	19.8	16.0
West Brookfield	1	15.2	8.0
Weymouth	3	4.2	5.0
Winchester	10	1.3	8.5
Woburn	3	13.1	51.1
Wachusett Reservoir	13	1.3	8.4
Sudbury Reservoir	7	2.3	8.4
Lake Cochituate	13	1.8	18.3
Framingham Reservoir, No. 2	2	1.1	11.0
Framingham Reservoir, No. 3	4	1.3	8.8
Hopkinton Reservoir	7	3.9	7.5
Ashland Reservoir	7	3.2	6.9
Spot Pond	2	0.6	9.0
Jamaica Pond	2	0.0	29.0
Upper Mystic Lake	5	3.1	12.6
Lower Mystic Lake	5	0.4	34.9

TABLE 8.

Aggressive Carbonic Acid.

(Parts per Million.)

City or Town.	Supply Surface or Ground	Hardness 1905 to 1909	Alkalinity.	Free Carbonic Acid.	Aggressive Carbonic Acid.
Abington	S	5	5.2	1.6	1.6
Andover	S	11	11.4	1.3	1.3
Ashburnham	S	10	13.0	3.1	3.1
Boston	S	13*	13.0	11.0	11.0
Braintree	S & G	10 & 19	9.6	1.4	1.4
Brookline	G	46	48.2	12.2	11.7
Brockton	S	5	8.1	1.7	1.7
Chicopee	S	9	9.2	3.4	3.4
Dracut	G	29	42.0	3.1	2.6
Fairhaven	G	21	12.0	21.7	21.7
Haverhill	S	17	16.8	1.4	1.4
Hingham	S & G	4 & 17	8.2	6.0	6.0
Ipswich	S	18	15.5	7.8	7.8
Kingston	G	11	11.5	20.3	20.3
Lawrence	S	14	12.3	4.2	4.2
Lincoln	S	8	3.0	5.5	5.5
Lowell	G	19	31.0	20.6	20.3
Marblehead	G	75	31.0	5.7	5.4
Marlborough	S	14	7.6	3.3	3.3
Methuen	G	30	28.0	2.9	2.7
Middleborough	G	23	17.5	41.4	41.4
Milford	S & G	11	10.5	15.2	15.2
Millbury	G	19	15.5	29.5	29.5
New Bedford	S	6	9.0	9.5	9.5
Newburyport	S & G	32 & 44	24.8	6.7	6.5
Newton	G	28	29.2	18.8	18.6
North Andover	S	14	14.0	1.4	1.4
North Easton	G	16†	10.0	3.4	23.1
Norwood	S	10	8.3	8.1	8.1
Palmer	S & G	7 & 18	10.5	5.0	5.0
Provincetown	G	12	3.9	37.4	37.1
Reading	G	49	63 0	16.4	15.6
Revere	S	13*	59.0	7.4	6.9
Sharon	G	39	27.0	15.1	11.8
South Hadley	S	7	8.7	6.0	6.0
Springfield	S	7	8.1	1.1	1.1
Stoughton	S	7	7.5	11.2	11.2
Wakefield	S	18	15.9	1.8	1.8
Waltham	G	36	37.3	29.3	28.9
Wellesley	G	39	16.0	19.8	19.8
West Brookfield	G	..	8.0	15.2	15.2
Weymouth	S	5	5.0	4.2	4.2
Winchester	S	13	8.5	1.3	1.3
Woburn	G	50	51.1	13.1	12.6
Wachusett Reservoir	S	9	8.1	1.3	1.3
Sudbury Reservoir	S	11	8.1	2.3	2.3
Lake Cochituate	S	19	18.3	1.8	1.8
Framingham Reservoir, No. 2	S	11	11.0	1.1	1.1
Framingham Reservoir, No. 3	S	12	8.8	1.3	1.3
Hopkinton Reservoir	S	9	7.5	3.9	3.9
Ashland Reservoir	S	9	6.9	3.2	3.2
Spot Pond	S	12	9.0	0.6	0.6
Jamaica Pond	S	..	29.0	0.0	0.0
Upper Mystic Lake	S	..	12.6	3.1	3.1
Lower Mystic Lake	S	..	31.9	0.1	0.2

* Metropolitan. † Easton.

Discussion.

Mr. Harrison P. Eddy.* I have been very much interested in Professor Whipple's presentation of the subject. I did not realize what the nature of his address was to be from the title of the paper, but I have had the privilege of discussing some of these subjects with him from time to time in the past few years, and I appreciate that he has done a great deal of very valuable work, which I believe will prove of interest and value as it is carried forward.

I wonder if one reason why water-works superintendents make so little use of the results of analyses is not because they are not in terms which are readily understood. A table of figures giving the results of chemical analyses is pretty dry reading. If there were some way by which the data could be put into popular terms, so that water-works superintendents would be able to visualize exactly what they mean more readily than they can at present, I think it might lead to very much greater use.

It seems to me that what the Professor says about the attractiveness of the water offers a field for development along that line. As that subject is given more attention, it seems to me that it will be possible to make reports in terms which are more popular, more easily understood, and perhaps more readily compared. The publication of results such as we have had in Massachusetts from year to year has been to a large extent useless to the general water-works superintendent. The consulting engineers have used them because they had to study details and make comparisons, not only for one supply at different times, but of general supplies and sources of supply. I do not feel therefore that the work that has been done has been lost or wasted, but rather that it might have been made more useful.

The diagrams which Professor Whipple has presented, if I understand him correctly, are made up from the records of these analyses, and if they could be visualized in some such happy manner as that, I am sure every water-works superintendent would be interested in the results. I hope that something of that kind may grow out of Professor Whipple's suggestions.

Mr. R. J. Thomas.† I would just like to say a word in regard to the water-works superintendents. In many of our cities they have no superintendent of water works. The water department is consolidated in what they call the Public Works Department, and generally the man in charge of the Public Works Department is not a water-works man, and frequently pays little attention to the water department. In these cities you will find that the water department is only a sub-department

* Of Metcalf & Eddy, Boston, Mass.

† Past President of the New England and the American Water Works Associations.

handled by a foreman, or perhaps two or three foremen, — according to the size, — one for pipe laying and others for various branches of the work. That tendency is growing in Massachusetts, and the water-works superintendent as we found him in the early days of this Association is disappearing, leaving no actual head (in many cases) of the water department, — certainly not a head who takes the interest in water-works problems and feels the responsibility they did in former days.

That may account for some of the failures to answer Professor Whipple's inquiries, and will no doubt in time make for inefficiency in the management and operation of water-works systems so controlled.

Mr. M. N. Baker.* I wonder if more interest might not be had by the water-works men, and perhaps by the city authorities as well, if more were done with bacterial results. It is not surprising that the ordinary tabulation of sanitary analyses of water should not arouse interest when presented to the water-works superintendents or to the citizens of a town. But if these were correlated with the vital statistics and the general health conditions of the city, and if they were brought to the attention, as they doubtless would be, of the local boards of health, some real use of the analyses might be expected. Certainly if the local boards of health are alive to their duty they will be deeply concerned with the right sort of analytical data on the character of the water, if accompanied with the right kind of interpretative comment.

That brings me to another thought that has been very much in my mind within the last few months, which is, whether, in view of the widespread diminution in typhoid, some other measure of the character of our water supplies and their effect upon the public health is not needed. This need has come very definitely to my mind in connection with the water supplies of Montclair, N. J., and Cambridge, Mass., to name only two places where there has within the past few years been considerable agitation over the character of the water supply, although both places are almost free from typhoid fever.

I am very much interested in this water from both the board of health and water-works viewpoints. I think that the board of health people and the water-works people, both in our cities and our technical associations, should put their heads together on this matter and see what the real significance of some of these things is, and whether we need some new measure of the sanitary quality of our water supplies.

Professor Whipple's paper, or that part of it which he has had time to read, is addressed very largely to the attractiveness of water. That I understand. But looking at it broadly, we can, if the subject is rightly presented, get money for water-works improvements if we can show, as we were able to show for very many years, that by a moderate expenditure the death rate of the city can be cut down.

* Associate Editor *Engineering News Record*, New York.

Mr. George A. King.* I would like to inquire if I rightly understood one sentence in Professor Whipple's paper. Speaking of the hydrogen ions and electrolysis, I understood him to say that the passage of electric current through the water pipe increased the electrolytic action.

Professor Whipple. I think that is probably true. During the past year we have continued our experiments on the corrosion of pipe in the Sanitary Engineering Laboratory of the Harvard Engineering School. Among other things we placed pieces of wrought-iron pipe, with and without brass couplings attached, in tanks of flowing water, and noted the relative corrosion. Even the slight galvanic current set up by the two metals appeared to cause a more general corrosion of the iron than was observed in the iron pipe alone, not only at the joint but all along the pipe. It is my impression that with a current of electricity flowing through the pipe this action would be somewhat increased. These experiments are not completed. We wish to have them carried on for a year before much is said about them, but they are extremely interesting.

One of my colleagues in the University told me some time ago some interesting facts in connection with his studies for the detection of submarines. When a current of electricity was sent from one end of the steel ship to the other, not all of the current went through the metal of the ship; a small part of it went out through the water in a sort of arc to a distance of 25 ft., and a still smaller part went out into the water to distances of 100 ft., or more. That is, not all the current went through the ship, as one might think it would do. By arranging a delicate apparatus in the water he could detect these stray currents, and he used that principle in locating submarines during the war. If that is the case, it seems possible that there may be minute currents of electricity in the water between the brass fitting and the pipes which will be effective, at some more distant place than the junction, so that rusting may be caused a good many feet away from the joint as a result of having the two metals connected. Electrolytes in the water would hasten this action.

Mr. King. The passage of the current through the water increases the electrolytic action?

Professor Whipple. Yes, and probably if a current of electricity is passed through the system the rusting will be faster.

Mr. King. Then would the grounding of telephone wires and electric-light wires have any effect?

Professor Whipple. That is one of the very things we are trying to find out. We do not know definitely as yet. We are making quite a number of studies of this sort at Harvard. They require time, but I think that in the course of a year or two we shall be able to discuss a lot

* Superintendent of Water Works, Taunton, Mass.

of those questions more intelligently than now and bring the results to the attention of the members of this Association.

MR. STEPHEN DEM. GAGE.* I have been very much interested in this paper, because for a number of years I have been trying to work out some satisfactory method of bringing home to the people the differences in our public water supplies.

As Mr. Thomas has brought out, a good many of the men who are nominally in charge of water works are not water-works men, and are mainly interested in seeing that the works are kept in operation at reasonable expense and that the necessary funds are obtained for this purpose from one source or another. So long as the state department of health passes their water as of safe quality they are very likely to consider that the supply is plenty good enough for all practical purposes.

It has seemed to me that if we are to raise the standard of many of our supplies, we will have to arouse and unite the sentiment of the people in the individual communities. One way to do this is to bring home to the people the fact that they are not getting as good a water as the people of some other community. Oftentimes the thoughtless water-works official can be brought to see the light in the same way, but unless he has public opinion behind him, he may not be able to get very far.

In the supervision of our various water filter plants in Rhode Island we are using this method to a certain extent. When we make our regular visit to a plant, if we find that the operating results are not as good as they might be, we tell the operator that John Smith at B—— plant is making better water, or is operating at a lower cost. He has visited John Smith's plant and knows that his own equipment is as good as Smith's, and his pride leads him to try to beat the other fellow.

I have a feeling that we might be able to accomplish something by working along the same lines with our unfiltered water supplies, if we had some simple system of grading such as Professor Whipple has outlined. If, for example, it were generally known that the water of one community was very much better than that of another, the people of the first place would be very likely to brag about it and thus perhaps arouse the citizens of the second community to support needed improvements in their own supply.

Some years ago I had large bottles of water from our different water supplies on exhibition at the various county fairs, with placards commenting on the varying character of the water, the effect of filtration, etc. This exhibit aroused considerable interest and many of our visitors stopped to ask questions, and most of them were intelligent questions. We felt that the educational value of these exhibits was sufficiently great to warrant us in repeating them for two or three years.

One incident occurred at one of the fairs, however, which illustrates the fact that there is another side to the question. Early in the afternoon

* Chemist and Sanitary Engineer, Rhode Island State Dept. Health.

a woman came up and said, "What is the matter with the Westerly water? I have just moved to Westerly from Woonsocket, and we can't drink the water, it has such a funny taste." The Woonsocket water is a surface water that ranges in color from 40 to 90 or more, and usually has a distinct vegetable odor, while the Westerly water is a clear, colorless, ground water with no taste or odor. I had always considered the Westerly water one of the best and most attractive waters in the state, while the Woonsocket supply wouldn't rank very high according to Professor Whipple's method of scoring. But this party had learned to like the dark-brown water, and the clean ground water tasted flat to her. Perhaps this serves to explain why it is sometimes so difficult to arouse popular sentiment in favor of improvements in some of our public water supplies. The people have learned to like them, bad as we sanitary engineers may think they are.

I should like to ask Professor Whipple one question. On what basis did he grade the odors of the Massachusetts supplies? Was it on the basis of the observed odors of laboratory samples, on the basis of counts of micro-organisms, or on the basis of complaints from consumers?

Professor Whipple. On the observed odors. We found it was not possible to do it on the basis of the microscopic organisms. because the State Department of Public Health records are kept in absolute numbers of organisms, taking no account of their size.

THE ECONOMY OF HIGH INITIAL COST AND EXTREME CARE IN SERVICE-PIPE INSTALLATION.

BY REEVES J. NEWSOM.*

[*Read September 14, 1921.*]

In cities and towns where the pressures vary between 35 lb. and 55 lb. in the major portions of the residential districts, the cleaning of service pipes to insure satisfactory force of water is apt to be a serious problem.

For the past ten years the number requiring cleaning in Lynn has been upwards of 2 000 per year, and has approximated 20 per cent. of the domestic services. The cost of this work varies from about $1 to $5 per job, depending on the accessibility and layout of the service, and averages around $2. To this must be added something for services which are made to leak when disturbed, while otherwise they might serve for several additional years.

This means on the average an expenditure of $10 and upwards in twenty-five years for the cleaning of each service pipe, and, what is of almost equal if not greater importance, there are five periods of more or less duration prior to each cleaning when the water service is unsatisfactory to the consumer, and when great inroads are necessarily made on the good-will of the public towards the Water Department, — something which should at all times be cultivated and guarded rather than injured or destroyed. The annoyance to the consumer is made more acute by the fact that inasmuch as the majority of these complaints are made with the beginning of the hot weather, and the lawn-sprinkling season, they come piling in at the rate of 25, 50, 75, or even 100 a day, and soon we find ourselves three or four weeks behind, and it is an exceptional consumer who will wait that long without feeling that he has a real grievance and that he is being discriminated against.

The coming use of the flush valve instead of tanks as bathroom equipment but serves to make more frequent and serious the lack of sufficient pressure.

In view of these things we have come to believe that a somewhat larger original investment and the use of extreme care in making service installations is not only economical in the end but good policy as well. We have, therefore, taken two definite steps to relieve the situation, first by increasing the size of service pipes for a given installation, and second by making it practically impossible for the water to come in contact with iron at any point from the main to the tee inside the cellar wall.

* Commissioner of Water Supply, Lynn, Mass.

Years ago hundreds of $\frac{3}{4}$-in. services were installed, in some cases for as large as three-family houses, and many of these are still in use. In recent years a 1-in. service with a $\frac{3}{4}$-in. corporation cock and gooseneck has been the ordinary size installed, but we have now gone a step farther and use this size only for cottage houses not over 30 ft. from the main, and for all ordinary installations and renewals we use $1\frac{1}{4}$-in. pipe with a 1-in. corporation and gooseneck. This size we believe will give ample water for all reasonable uses, and our next care has been to insure the maintenance of this full size for a long term of years.

We use wrought-iron service pipe, and line it with cement. The common difficulty of a non-concentric lining has been overcome by certain special features of the cones used for shaping the cement. We now use a single cone of more than the ordinary length, the last six or eight inches of which is $\frac{1}{16}$ in. larger than the front section. Two sets of spring steel wings are provided, one near the forward end and one slightly back of the middle, which centers the cone rigidly. The enlarged part of the cone smooths out and fills in the grooves made by the wings, and because it is attached to the remainder of the cone it cannot drop, due to its weight, as does the ordinary follower.

Cement-lined service pipes were used by the department from 1871 to 1890, and many of these pipes are still in service. They were installed, however, with unlined fittings, and it has been necessary to take them up, due to plugging of the latter. In all cases the pipe taken out, even after forty years' use, is in good shape, and the inside is as clean and smooth as the day it was installed. We have learned, therefore, that it is in the connections that the trouble develops, and that it is here that we must exercise our greatest care.

Beginning at the main, the first precaution is to prevent the stoppage of the corporation, and our method is to use cocks which have an extension beyond the threaded portion entering the main, about $\frac{3}{4}$ in. in length, which is similar to the old eel guard, except that it is solid rather than slotted, and is open full size at the end. This measure is especially valuable for tappings in 12-in. pipes and above, where the thickness of iron prevents any appreciable part of the cock from protruding through the main. This type of corporation makes it necessary for the rust action taking place where the drill has broken through the cast iron and destroyed the coating to pile up nearly an inch thick before it begins to close over the end of the cock, and usually, due to the slowness of the action when the iron is partially covered with rust, this will require a very long time.

Where the joints are made in the service line there are two opportunities for rust formation, the cut end of the pipe and the breaking back of the cement lining if the pipe is cut with an ordinary pipe cutter.

If the cut end of pipe is exposed in the couplings, only ordinary rust action takes place, but if it is exposed in the brass fittings, very much more rapid galvanic action takes place, due to the presence of brass, iron, and

water, the latter always containing enough salts to make it an electrolyte. We line our couplings, tees, elbows, and forty-fives with lead, and also put a ring of the same material in the female solder nipples in the end of the goosenecks and in the curb cocks.

The solder nipples are tapered, which allows entering a tool part way, until it strikes the side of the fitting and prevents the lead going through when it is poured. The making of the lead ring in the curb cocks is greatly simplified, and the cost of this work is more than paid for by using a cock one size smaller than the pipe, with enlarged outlets. For example, for use with $1\frac{1}{4}$-in. pipe a 1-in. curb cock with $1\frac{1}{4}$-in. outlets is used, which gives a shoulder against which the inside lining tool is held. This tool has a flat tapered end, which allows a tight fit against the shoulder and prevents any lead from going through when poured. The cocks so used are substantially the same size as the larger-sized pipe when lined and give plenty of waterway, for, when the formation of rust is precluded, the need of a large, roomy curb cock disappears.

The bushings used for the lining of all fittings are carefully regulated so that they screw in only five or six threads, which assures the pipe coming solidly in contact with the lead, so that the raw iron will be completely covered. To insure a tight fit between the lead and cement, the inner half of the inside end of the bushing is beveled outward on a 30° angle, so that the cement and lead come in contact slightly in advance of the iron and lead.

The final precaution is to prevent the cement from breaking when the pipe is cut, so that the last opportunity for the contact of water with iron will have been taken care of. This is done by cutting all pipe in the shop by a metal cutting machine which, to all appearances, is a power hack saw, made with heavy accurately ground bearings, and which gives an absolutely square end to the cement as well as to the iron.

This is accomplished by having a man from the engineering department follow up the service gangs a couple of hours after they start digging for an installation, and take measurements of what will be required for each job. These measurements not only serve the engineering department in making the records, but are immediately turned in to the stock department and the pipe and fittings are gotten out and are partially made up. A little later the trucks taking care of the service gangs return to the shop and deliver the material to the jobs, where it is slipped into place.

The additional cost of services so laid is, on the average, approximately \$5.50, made up as follows:

Larger corporation	\$0.75
Larger gooseneck	1.25
Larger curb cock	.85
Larger pipe, 6c. per ft.	2.40
3 lead rings in brass fittings	.25
	\$5.50

The finished product compares favorably with either lead or brass for longevity, and at very much less cost.

It is our firm belief that all these things, some of which may seem more or less superfluous, are fully justified, especially in cities where pressures are relatively low. It is only to be regretted that those to benefit most will be the water-works officials twenty to thirty years hence, while at present we must continue to take the criticism of the dissatisfied consumers and to dig up well-paved streets to remove pipes which were installed in the past with less care than we now exercise.

Discussion.

Mr. J. M. Diven.* How is the outside of the wrought-iron pipe — or wrought-steel, I suppose probably it is — protected? Is it also covered with cement?

Mr. Newsom. We use wrought-iron pipe, not steel, and do not put any protection on the outside of the pipe, but use ordinary black pipe, except where it is to be laid in a part of the city where we encounter salt water, in which case we use galvanized pipe. When we buy galvanized pipe, we buy it galvanized on the outside only, so that there will be no likelihood of any irregularities inside the pipe to interfere with the proper lining with cement. The pipe I spoke of as having lasted forty years or more in the ground was only ordinary black pipe.

Mr. Diven. What does it cost per foot to line $1\frac{1}{4}$-in. pipe?

Mr. Newsom. Between $2\frac{1}{2}$ and 3c. a foot for $1\frac{1}{4}$-in. pipe.

Mr. Diven. Would you recommend using cement-lined where the pressures are high as well as where they are low?

Mr. Newsom. I think the advisability of using cement-lined pipe is entirely independent of the pressure.

Mr. David A. Heffernan.† Mr. Newsom and I have corresponded relative to the lining of pipe. I have been lining wrought-iron pipe with cement for more than a dozen years. This was a good plan as far as it went. The brass fittings used in connection with a wrought-iron service generated a galvanic current, so that it became necessary early this year to line all fittings from main to meter where they are made on to the iron pipe, thus preventing the brass from coming in contact with the iron at any point where the water would reach them. This makes more work and a more expensive service, but I can see no other way of overcoming the troubles we are meeting, and it is my confident belief that those superintendents who adopt this policy will not regret it.

Mr. J. E. Garrett.‡ I should like to ask Mr. Newsom if he uses reamed pipe, or ordinary black pipe unreamed, and if with the special

* Secretary, American Water Works Association.
† Superintendent, Water Works, Milton, Mass.
‡ Civil Engineer, Stamford, Conn.

lining cones that he has it is unnecessary to ream the pipes before lining them?

Mr. Newsom. No; the cones will not take care of irregularities in unreamed pipe. We use short lengths, — that is 14- to 16-ft. lengths of black, reamed pipe. It has been our experience that even when you buy black, reamed pipe there are certain irregularities in that pipe which cause trouble when you use solid wings, but not with spring steel wings.

Mr. Carleton E. Davis.* You spoke of the larger-sized pipe. Is the service charge based on the size of the pipe?

Mr. Newsom. I regret to say that we have not gotten quite into that stage of charging yet. We do not have a service charge.

Mr. Davis. But this service pipe does not affect the charge for water?

Mr. Newsom. At the present time it does not. It probably would if we were figuring it just that way, although I believe that the amount saved in cleaning the pipes will be more than the cost of putting those pipes in this way, so that we will not require any more revenue than we have now. It is simply spending it in a different way.

Mr. Diven. What is the method of cleaning the pipe?

Mr. Newsom. We use the ordinary methods in cleaning. We either insert rods with cutters on the ends of them, or else we in some cases use hollow tin tubing, the same as is used for thawing pipe. That is simply run in and out. When we get to the corporation cock and find that stopped up so that we can't push in a reaming tool there, we use an instrument which we call a spudger, which is a section of brass pipe which we secure to the end of the service pipe in the cellar. Into that we fit a wooden plug which will just slip into the brass pipe. We then turn on the pressure, allowing the spudger to fill, meantime holding the water back with the wooden plug. The latter is then hit with a hammer, which causes water hammer and drives any obstruction out of the corporation cock.

Mr. R. H. Ellis.† I would like to ask Mr. Newsom if in his experience with cement-lined pipe he has ever found any trouble with the cement cracking or pulling inside of the pipe, provided a heavy fill has been put on top of the pipe, causing a slight sag, or something of that nature. My reason for asking is that in our department at North Andover we are busily engaged at the present time in removing practically all the cement-lined pipe that we have, owing to the fact that the cement has scaled off, allowing corrosion to set in in the interior of the pipe.

Mr. Newsom. I have never had any experience of that kind. I am inclined to believe that if the cement peeled off, or cracked off, due to nothing more than simply a sagging in the pipe, it was improper construction when the pipe was originally lined, because our experience has been that pipe properly lined can even be bent around a small angle without

* Chief Bureau of Water, Philadelphia, Pa.

† Superintendent, Board of Public Works, North Andover, Mass.

injuring the cement. While we do not do that as a matter of practice, it certainly is more severe than a sag in the pipe would be.

MR. BERTRAM BREWER.* When the speaker was in Waltham and in charge of the water department, one of the things that came up was the question of the use of cement-lined pipe. In the years gone by it had been used to a great extent, but suddenly, without apparent reason, those in charge gave it up and began using plain galvanized pipe instead. An investigation of the situation with some of the foremen who were directly concerned with the work disclosed the fact that, just as Mr. Newsom's paper suggests, the work had been very carelessly done and some of the cement lining had separated from the iron and the pipe had become plugged. It proved to be very unwise to give up the use of cement-lined pipe, especially in Waltham, so we began using it again with more skill and found no difficulty in getting a permanent lining.

While I am on my feet I just want to say that I do not know of any literature that contains more valuable information on this general subject than the volumes of the New England Water Works Association JOURNAL. A Committee on Service Pipes made a valuable report, a few years ago, published in the September number of Vol. XXXI.

I do not think that there is proper realization of the fact that carbonic acid is extremely deleterious to metal, on account of its corrosive action. In Massachusetts many of the ground-water supplies contain carbonic acid, particularly such water as that of the Cook wells in Lowell, the Waltham water, the Newton water, and many others. No one should think of laying connections where there is carbonic acid in the water unless cement-lined pipe is used or some equally good protection is secured as that provided by the cement.

MR. GEORGE A. KING.† I should like to ask Mr. Newsom if he has ever used what I call the Boston plan of cleaning, — using a force pump to drive paper through the pipes?

MR. NEWSOM. No, I have never used that. We have had success with the method we have used and have found it very effective.

MR. BREWER. I have tried out the paper-plug method of cleaning old services very thoroughly and should say in over half of the cases where it was tried success followed the attempt.

MR. TIMOTHY W. GOOD.‡ I am very much interested in Mr. Newsom's paper. I want to say, for the benefit of the members, that in the city of Cambridge, Mass., with approximately 18 000 services, we believe in a proper method of lining on original installations. We have used nothing but lead-lined pipe for the past fourteen years, and have never had any trouble, except that at times you might get slight corrosion at the main where the corporation cock is tapped in; this, however, is easily remedied

* Assistant Engineer, Massachusetts State Department of Public Health.

† Superintendent, Water Works, Taunton, Mass.

‡ Superintendent, Water Works, Cambridge, Mass.

by means of our cleaning rods. We are firm believers in rigid connections at the main. We put a coupling right on the corporation cock, and our experience has shown that you get sufficient expansion through the basement wall, and the least number of joints you have out under the pavement the better it is for the service. We consider the added cost of lead-lined pipe a good investment. In fourteen years we have never had to renew, and we know that we will go fourteen years more.

Mr. Gordon Z. Smith.* I should like to state that I had lately an experience in a little town in this state in cleaning out various kinds of services, except lead pipe. There are no lead services there. Some years ago the department manufactured cement-lined pipe of their own, and at the joints there was a brass thimble inserted. The joint itself was a regular iron-pipe joint. After some years those cement-lined services did fill up, particularly at the corporation connection and at the curb box and at each joint. The water department installed the service from the water main to the curb box, so that we were responsible for it and its renewal. Some time in 1914 I discovered the method that was being used in Boston in cleaning out services with the use of a force pump and a wad of tissue paper. It worked out very successfully in most instances, even with cement-lined pipe. I have had curb cocks so filled up that one couldn't see any light through them, they were absolutely filled full, and those were cleaned out as good as new. But where the pipe lining had broken and the pipe had tuberculated along in the middle of its length, we couldn't do anything in cleaning that out, because it was something that the paper would not handle. If it did, there would so much get ahead of the paper wad that the pipe would be absolutely plugged. We had some three years' experience with it while I was there, and it saved us quite a little money in the renewal of services.

Mr. W. C. Hawley.† I am wondering if a part of our service-pipe trouble is not due to the use of zinc in the mixture of which our corporation cocks and curb cocks are made. I came to the conclusion, a good many years ago, that it would be better to have a mixture 88–10–2, the two per cent. being of lead. It makes it a little harder to machine, but I think it is better than a mixture containing zinc.

Mr. Diven. You better bring that before the Committee on Fittings.

Mr. Lincoln Van Gilder.‡ Our own experience has been that standard galvanized pipe for services, or a $\frac{3}{4}$-in. pipe, will close up in about ten years, and that the same pipe with lead lining lasts indefinitely. We have never used the cement, and that is something I have no personal knowledge of. We sometimes have difficulty with a corporation cock or a curb cock.

* Chief Inspector, Bridgeport Hydraulic Company (Conn.).
† Chief Engineer, Pennsylvania Water Company.
‡ Superintendent, Water Works, Atlantic City, N. J.

MONEL METAL AND ITS SUITABILITY FOR WATER-WORKS USE.

BY H. S. ARNOLD.*

[Read September 14, 1921.]

Monel metal, a natural alloy of nickel and copper produced by the International Nickel Company, is attracting considerable attention in engineering circles because of its peculiar properties which make its field of usefulness very broad.

Since Monel metal has been termed a natural alloy, and since to many its history is obscure, I will describe briefly the source of supply and method of manufacture.

Monel metal comes from an ore of nickel and copper occuring in the Sudbury district of Ontario, Canada. The ore deposits of this district constitute the largest known commercial nickel deposits in the world. The Creighton Mine, one of the International Nickel Company's properties, is the largest producing nickel mine in the world. The ore as mined contains considerable sulphur. By heap roasting, about half of this sulphur is eliminated. The roasted ore is smelted in blast furnaces to a matte containing about 25 per cent. nickel and copper. This matte is blown in Bessemer converters to approximately eighty per cent. nickel and copper. The converter product, called "Bessemer matte," is shipped to the Company's New Jersey refinery, where it is pulverized, dead roasted to remove sulphur, and finally reduced with charcoal in oil-fired reverboratory furnaces to Monel metal.

The furnaces are tapped at about 2850° F., and after deoxidizing in the ladle with manganese and magnesium, the metal is chill cast into ingots for rolling and forging or into blocks for remelting purposes. Monel for sheet rolling and for remelting carries about $\frac{1}{4}$ per cent. manganese, while for rods, forgings, wire, etc., the manganese is raised to $2\frac{1}{2}$ per cent. Metal for sand castings usually has about 1 per cent. silicon added. The alloy, Monel metal, thus produced contains approximately 67 per cent. nickel, 28 per cent. copper and 5 per cent. other metals, chiefly iron, manganese, and silicon.

It is a single solid solution which looks and in general acts like a pure metal. There has been no separation nor any addition of nickel or copper during the refining process. The nickel-copper ratio remains the same from ore to finished metal, hence the name "natural alloy."

* Of the International Nickel Company, New York.

Monel can be cast, forged, hot rolled, or cold drawn. It may be autogenously welded, brazed, soldered, stamped, machined, and polished.

It is annealed by heating to 900° C. It is hardened only by cold work.

Physical Properties.

In its physical properties it resembles medium steel to a certain extent. Its tensile strength forged or rolled runs from 75 000 to over 100 000 lb. per square inch, depending on the amount of work and the finishing temperature. The elastic limit will be from 40 000 to 75 000 lb. per square inch, elongation 30 to 50 per cent. in two inches, reduction of area 50 to 70 per cent. It is comparable to an annealed medium steel in hardness, its Brinell numbers running from 145 to 170. The Shore scleroscope hardness is about 27. The yield point under compression runs from 60 000 to 70 000 lb. per square inch.

Values for the torsional strength of hot-rolled Monel metal are yield point 50 000 to 80 000 lb. per square inch, maximum stress 75 000 to 90 000 lb. per square inch. Shear tests give, for double shear, 90 000 to 127 000 lb.; for single shear, 45 500 to 60 000 lb. per square inch. A research laboratory (G. and J. Weir, Limited, Cathcart, Scotland) has recently made an interesting series of comparative Izod impact tests on several different metals, and the position of Monel metal at the top of this list is worthy of comment. The metals thus compared were: Three-quarter inch rolled mild steel rod, wrought iron, rolled brass rod, forged copper, rolled Monel metal rod, cast admiralty gunmetal, iron cast in green sand, and high-tension bronze cast in chill. The results are expressed in foot-pounds absorbed in breaking or bending, and follow in the order of their magnitude.

Cast iron	.08
Admiralty metal	8.0
Rolled brass	23.0
High-tension bronze	25.5
Forged copper	46.0
Wrought iron	58.4
Mild steel	76.7
Monel metal	113.7

All pieces were broken in the test except copper, wrought iron, mild steel, and Monel metal. Tests at the Bureau of Standards in Washington verify these figures and give Monel metal a higher figure than heat-treated alloy steels of twice its tensile strength. This high value for the resistance to impact seems a matter of course to one who has seen Monel metal parts subjected to sudden severe shocks which would be destructive to other metals of the same strength, for in these cases they have seen Monel metal only bent or distorted in such a manner as to require straightening to be again put into service, while the other metals of similar or greater tensile strength were broken and ruined for further use. There was an interesting

illustration of this some time ago, on a destroyer which came into a navy yard with one of its turbines out of commission. Examination revealed the fact that a nickel steel bucket had snapped when revolving at high speed, and before the turbine was shut down all the other steel buckets were broken off short. None of the Monel metal buckets were broken, in spite of the fact that steel buckets were wedged in among them in such a way as to bend them badly. It was necessary to replace the steel buckets with new ones, while those of Monel metal needed only to be straightened.

The modulus of elasticity is about 25 000 000, about the same as wrought iron and twice as great as brass. This comparatively large value has bearing in the construction of such pieces of apparatus as propellers, where distortion may cause a great loss in efficiency.

The ultimate strength of sand-cast Monel metal is about 75 000 lb. per square inch, yield point 40 000 lb. per square inch, elongation 30 per cent. in two inches.

The hardness is about 20 Shore, 100 Brinell.

The tensile properties of cold-drawn or rolled wire, rod, or strip, vary largely according to the cold work, degree of annealing and gage. The ultimate strength may be produced from 85 000 to 160 000 lb. per square inch, yield point 50 000 to 100 000, elongation 30 per cent. to 1 per cent., depending on the hardness, which may be as high as 45 Shore when heavily worked and not annealed. When annealed, the hardness may be as low as that of hot-rolled material.

The melting point of Monel metal is 2480° F., its specific gravity 8.87 cast and 8.98 rolled, — 14 per cent. greater than steel. Its coefficient of expansion between 70 and 212 F. is .00000765 per degree, 15 per cent. greater than steel and 18 per cent. less than copper. Its electrical resistance is 256 ohms per million feet and temperature coefficient .0011 per degree Fahrenheit. Its relative heat conductivity is one fifteenth that of copper. The amount of shrinkage in cooling from the molten state is $\frac{1}{4}$ in. per foot.

Monel metal is, perhaps, the best general metal for resisting acid, alkalies, and general chemical corrosion. There are other metals, of course, which are more resistant to certain corrosive agents, but Monel metal, whose solution potential is well below hydrogen and acid resisting metals, is in general attacked less seriously than any other metal. It combines with its slow rate of corrosion the property of corroding evenly with little pitting or local attack.

It withstands successfully such corrosive actions as that of atmospheric conditions, fresh or salt water, wet or superheated steam, gases of combustion, metallic mercury, and the oxidizing influence of heat up to 1 000° Fahrenheit, below which point only superficial oxidation takes place. It has been shown by experiment that benzoic, citric, hydrofluoric, lactic, dilute phosphoric, picric (in the cold), salycilic, tannic, hydrocyanic acids, and carbolic acid have practically no effect on the metal. The evidence seems sufficient that it is resistant to all fruits and fatty acids

and phenols. The action of foods is not severe on Monel metal, and food may stand in vessels of it for some time without acquiring a foreign flavor. Tomatoes and clams are exceptions to this. They have been found at times to be so affected by long standing in Monel metal as to make them unfit for use.

Pure alkalies will, in general, attack Monel metal only very slightly. Some cases have been known, however, where alkalies in the presence of their salts have affected the metal, and it may be stated as a general rule that such mixtures will produce definite corrosion.

Principal Types of Uses and Related Properties.

One general type of use is for structural purposes where it is subjected to severe weather conditions. This includes its use for roofing sheets, skylight frames, window screens, etc. The properties which enter here are its resistance to weather corrosion and its strength. An example of this use is the roof of the Pennsylvania Terminal, New York City, which is entirely of Monel metal and which has needed only minor repairs since it was built. Even the minor repairs have been caused by faulty laying, and not by any failure of the metal. Another is that of Monel metal screening which has recently been removed from the summer home of an officer of the Nickel Company, on the Jersey coast, after nine years of service exposed to weather and spray carrying sea breezes, winter and summer. When, after this period, it was removed for examination and exhibition it showed little signs of wear or corrosion. This service has been estimated to be equivalent to twenty-five years of such service as ordinary screening receives when only in use during the summer.

Another general type of use is for household, hotel, and hospital hardware, including trimming and fixtures where a bright permanent white polish is desired, other hardware, plumbing parts, cooking and serving utensils, table flat ware, washing machines. These uses require that the metal be resistant to the action of foods, hot and cold, and to cleansing agents, also that it take and retain a good polish.

In regard to its use in superheated and wet steam and hot water, some very interesting data have been presented to the Engineers Society of Western Pennsylvania by J. Roy Tanner and George J. Stewart. Monel metal has given good service in valve seats, rings, bushings and stems, pump rods and plungers, meter parts, stop cocks, etc. The important properties here are the retention of tensile strength at high temperatures, similarity in tensile and expansion qualities to steel, and tendency to wear or corrode evenly if at all.

Its resistance to oxidation and to gases of combustion at moderate temperatures makes it serviceable in oil combustion parts, spray valves, ignition points, welding torch heads, conveyors and stirrers for furnaces, internal combustion engine valves, glass rollers, and blowpipes.

Being resistant to many forms of chemical corrosion and at the same time of high tensile strength, impact- and wear-resisting properties, it is used in chemical work such as pickling crates, pins, tie-rods, nuts and washers, evaporating and drying pans, fourdriniers, filter cloth, textile machinery, general acid and chemical handling work.

Some Special Uses and the Related Properties.

Of particular interest in the Pittsburgh district is the use of Monel metal parts in the process of pickling steel sheets and slabs in sulfuric acid. The metallic equipment of this work consists of crates, pins, hooks and bales, tank tie-rods, nuts and washers, and tank drains. The original cost of Monel metal for this work is greater than that of most of the anti-acid bronzes which are used for the same purpose. However, the greater resistance of Monel metal to the acids and pickling agents, combined with its strength and resistance to impact and its amenability to re-working, make it cheaper in the final analysis.

If Monel metal is to be used where exposed to hydrochloric acid or its fumes, it should be subjected to a preliminary trial, as it has been found that in some cases it will not stand up, while in others it withstands the action of the acid with entire satisfaction. The laws governing this action have not been thoroughly worked out. It is evident that local conditions and methods of handling have a great deal to do with its ability to resist this acid. It is probably true that Monel metal will resist it, however, better than any other common alloy. In no case is it recommended for nitric, chromic, perchloric, hot picric, or phosphric acids, or such oxidizing salts as ferric sulfate, copper sulphate, mercuric chloride, or molten zinc salts. Neither will it resist molten metals or molten sulfur.

It resists well the action of dry chlorine and sulfur gases.

Another important special use of Monel metal is in turbine buckets, especially for marine turbines where, the pitching and tossing and twisting of boats in a heavy seaway, operating contrary to the gyroscope action caused by the high speed of the moving parts, sets up strains and stresses which would cause other metals to crystallize and snap off, Monel metal remains unaffected. Another factor in its favor for this work is its ability to retain a large percentage of its tensile strength and other properties at the temperature of the steam operating the turbines.

In power plants its ability to retain tensile strength at steam temperatures and to resist the erosion of live steam give it a large use. Valve trim and turbine shrouding are often made of it. Pump rods and liners in pumps that handle water containing a large amount of acid or other corrosive agents are generally of Monel metal. In hydroelectric power plants large impellers cast of Monel metal are often specified. In the latter case bronze has been discarded because the erosion of the water eats away and roughens the vanes. Monel metal is admirably suited to replace it because of its property under such erosive action, instead of becoming pitted and

roughened, of remaining bright and smooth, thereby giving maximum efficiency.

Several years ago, Brezowsky and Spring of the Crane Company conducted experiments comparing Monel metal to other alloys for use in valves made by the Crane Company for handling steam. All of these tests showed that Monel metal was better suited for their purpose than the other metals tested. It retained its physical properties better than practically any other alloy, and where this was not the case the difference was very slight. Its strength was either greater at corresponding temperatures due to its greater initial strength or it was more resistant to the corrosive and erosive properties of the superheated steam. These properties have been more recently checked in the laboratory of the International Nickel Company and in laboratories abroad. Tanner and Stewart in their paper showed that for handling superheated steam the only satisfactory valve was one of cast-steel body with Monel metal mountings. It has been repeatedly compared with other alloys for this work and none has so far been found to approach it.

Its heat-resisting qualities, while not as good as nichrome or chromel, or pure manganese nickel, are such as to make it well suited for certain heat-resisting uses. It has been found, for instance, that Monel metal exhaust valves in internal combustion engines give excellent results.

In the mining industry, Monel metal is found well distributed in the form of pump rods and liners, mine screens, and coal chutes. In the latter case its ability to resist abrasion as well as corrosion have been the factors governing its selection. At the same time Monel metal should not be used in mines which have an appreciable amount of ferric sulfate in the water, as this salt has a decided corrosive action on it.

The ability of Monel metal to withstand the action of weak acids and other corrosive agents of foods gives it value in the handling and preparation of food products. Packing-house equipment which comes in contact with brine and salt is largely made of it. Meat and fruit slicing machines, canning apparatus, dairy machinery such as butter handling machines, milking machines, separators and pasteurizers, have parts of this metal. In the kitchens of some of the large, new, up-to-date hotels, Monel metal is prominent in the form of steam table-tops, coffee urns, pots, and pans.

A growing use of Monel metal for direct personal interest to many is as a metal for the manufacture of golf club heads. The use of Monel metal does away with the necessity for grinding and polishing to keep the clubs bright, and the clubs will therefore not become lighter with use. Being of as great resilience as steel and slightly higher in specific gravity, Monel metal heads give a somewhat greater distance to the ball.

Experiments are being conducted in New York City to determine the suitability of Monel metal for parts in telephone and telegraph subways. Here the metal parts are subjected to seepage from the sewers and the filthy salt water that often fills the subways along the water front. These waters are exceedingly corrosive. Ladders for the manholes, locks for the

covers, and similar parts have been made of Monel metal for trial. To date these parts have been in service nearly two years in the worst manhole in the city and are as good as when put in, while parts made of other metals have lasted, at best, only a few months.

Some of the other interesting places where Monel metal serves a special purpose, which are too numerous to discuss in any detail, may be mentioned as: Parts for ordnance and for submarine construction, incinerator machinery, sewage handling machinery, lavatories, textile machinery, storage battery casings, burning points and racks for enamel ware, plugs and other parts in the manufacture of gasoline in Burton stills, oil-handling machinery, parts of tempering furnaces, tank linings for acid and alkali, gas-engine water jackets, chain to resist weathering, wire rope, sash cord, resistance wire, rivets and nails, dyeing machinery, refrigerating machinery, and sugar-refining equipment.

So far I have not dealt directly with the suitability of Monel metal for water-works uses.

That Monel metal is worthy of consideration by water-works engineers is evidenced by its present use in this field.

Monel metal is in constant demand for the gear parts in water meters, especially in the middle west and on the Pacific coast.

Monel metal pump-liners, pump rods, valves and valve stems have excellent records of service dating back to 1907. The Boston Fire Department installed Monel metal valve stems in the high-pressure fire hydrants in 1909. The results have been very satisfactory.

Monel metal has been used to replace bronze anchor bolts on the Ashokan Dam. It also finds use in filter screens, and in water purification system. Chlorination parts, namely, valve stems and seats, have been standard for the past eight years.

The field is one in which we have not gone deeply, yet it would appear from a general survey that the opportunities for Monel metal are large. It is here, perhaps, that the non-corrosive properties of Monel metal will be of primary interest. We have become less and less confident of our ability to theorize about the behavior of metals toward corrosion under actual service conditions, and realize that corrosion tests to be of practical value must be made in the field or at least upon a comparable scale. Yet it is appreciated that the use of any particular metal is rarely based upon the sole property of the resistance to corrosion. In fact, I venture the assertion that resistance to corrosion alone, although a necessary factor, is quite frequently not the determining one of practical serviceability in any particular "anti-corrosion" piece of construction, but some other property often entirely unrelated to it. As a corollary to this, I can state from my own experience that materials may be sufficiently resistant to corrosion for jobs requiring this property, but their actual use for it is quite out of the question on account of their failure in other and quite different directions. The engineer is greatly in need of a material of corrosion-resisting proper-

ties which, in addition, is otherwise well balanced in its physical characteristics and without serious deficiencies. It must be readily subject to the usual processes of fabrication; welding, soldering, forging, casting, machining, rolling, drawing, stamping, etc. It is in this respect that most specialized corrosion-resistant metals display inability to meet requirements without expensive and troublesome changes of design.

Finally, a material to be generally useful must be available in commercial forms. The importance of this qualification will be fully appreciated by all those familiar with commercial development of any sort.

Discussion.

Mr. J. M. Diven.* Has this metal been used by the valve manufacturers for valve stems? If so, about what additional cost would there be over bronze metal?

Mr. Arnold. Practically all of the large valve manufacturers are well acquainted with Monel, but they have given their fullest attention to steam valves. The Crane Company, however, has made some large valves for water-works uses.

The high-pressure valves previously mentioned were made for the Boston Fire Department by another manufacturer, hence we have no record of costs. In general, Monel castings will cost about twice as much as bronze, and fabricated Monel about two thirds more than bronze.

Mr. Carleton E. Davis.† Is that cost on a pound per pound basis, or is it allowed for smaller size but possessing greater strength?

Mr. Arnold. Pound per pound. There is, of course, quite a chance to make a saving in size, providing you want to do it. It is usually a case where for safety we take advantage of a stronger material rather than cut down, although I know the latter is done in many cases. For instance, in meter parts, I believe they are cutting down. In casings and the like, they cut down considerably, from a cast to forged material. Where they have found it practicable to use a stamped or forged material to replace a casting, they have been very successful in cutting down weight.

Mr. William Ross. I would like to ask whether your company will sell pig now. I asked some time ago, and they would not sell pig but would sell castings; but for experimental purposes that was not very practicable.

Mr. Arnold. No, there is no objection at all to that. They will be glad to sell either in the form of 50-lb. pigs or in the form of shot.

If you have any difficulty I will be very glad to have you write to me personally.

Mr. Diven. I do not think the water-works operator would hesitate to pay twice, or several times, the cost of a valve stem, if he could get a valve stem that would not give out.

* Secretary American Water Works Association.
† Chief, Bureau Water, Philadelphia, Pa.

Mr. Samuel E. Killam.* I might say that last year, on one of our hydraulic valves, we were unfortunate enough to allow it to freeze, and it cracked the cylinder. It was a case of replacing that cylinder. I was very much surprised, when the foreman took the cylinder off, to have him report that the valve stem came out. It was 88–10–2. And later in the evening he called me again and said it was entirely out. So that I went up to the works. I found that where the valve stem had entered the nut it was broken off short. Why it broke off I have not been able to reason out. But we replaced that particular one with Monel metal. That is a regular 36-in. hydraulic valve. I believe it is something that will be worth looking into later for valve stems in large valves.

Mr. Diven. That is a little heavy to have breaking out, is it not?

Mr. Killam. Yes; it is the first time I have caught it.

Mr. Lincoln Van Gilder.† A couple of months ago I was informed by a gentleman in Philadelphia who represents a distributing firm, that there seemed to be a lack of uniformity in the metal, and that where you expected to get a non-corrosive article you got one that was quite readily attacked. I was wondering whether that had been permanently cured yet, and whether you can produce Monel metal that you can reasonably guarantee as anti-corrosive.

Mr. Arnold. Yes, we do. I think perhaps the statements of failure are perhaps a trifle overdrawn. I am very sure from our own records that I can state positively that the percentage is a very small fraction of 1 per cent. And I think you will find the company will be very glad to make a replacement in case of unsatisfactory material of this sort.

Mr. Killam. I would say that in figuring up the cost, as near as I could estimate, it was about 75 per cent. more for the Monel metal.

Mr. Arnold. Did you have your own material machined out for you?

Mr. Killam. Yes.

Mr. Arnold. There is the difficulty that is being rapidly overcome, — cost of machining. A great many machine shops have complained of the difficulty of machining Monel metal, and they have charged exorbitant prices for machining. There is really no reason why there should be an extra charge at all, or, if any, only a very small one. It is merely the case of a little precaution in dressing your tools to get proper cutting quality.

Mr. Killam. Wasn't that due particularly to the poor American tools made during the war?

Mr. Arnold. A great deal of it. Then the fact that a great many machine shops took it as one of two things, — either as being like bronze, and giving it a bronze treatment, or being like steel, and giving it a steel treatment; and neither of them is entirely successful.

* Superintendent, Distribution Sections, Water Division, Metropolitan District Commission, Boston.
† Superintendent, Water Works, Atlantic City.

PROPER UNDERGROUND RECORDS.

BY R. F. JOHNSON.*

[*September 15, 1921.*]

Mr. Chairman and Gentlemen of the Convention, — I have no paper. I submit, however, an exhibit which I am going to leave on the clerk's desk for any of you to look at who may wish to do so, so that you may see how we keep our underground records.

In our city our water department was managed, up to about seven years ago, by a board of water commissioners, and seven years ago the form of government was changed so that the city is now managed by a commission. Our people believe in associations, and when they employed me as superintendent, quite a good many years ago, I was asked to take the position on the first of July, and the first thing they instructed me to do was to attend a meeting of the American Water Works Association in June, before I ever had anything to do with the water works. Since then I have absorbed a great deal from my attendance at the meetings of the American Association, and from the literature of this Association, to which I have been a subscriber for quite a good many years. And I thought it was no more than fair, after I had absorbed so much, to undertake to contribute a little, so that I asked one of our boys in the drafting room to make me a sample page of our underground records.

Previous to my being appointed superintendent, I was comptroller of the city, and previous to that time I had been in the accounting business, and I always believed that anything in that line should be left by the operator, or bookkeeper, or whoever it might be, at night, so that if he should never again appear that somebody else could take it up in the morning.

When I got into the water-works business I conceived the same idea. About the first thing I ran across when I took charge of these water works was to overhear the men say, "Well, John, didn't you, some years ago, put down a long connection along Brockway Street, and if you did, when we extended the main itself what became of that connection?" Another question would be, "How far is the main out from the curb on a certain street?" Another question would be as to the exact location of a valve. And I found that they were continually hunting up references at the expense of a great deal of time.

Then, when it came to the service connections, that was worse yet. I found reference books in the office saying that certain blocks had service

* Commissioner, Department of Light, Water, and Sewers, Saginaw, Mich.

connections of a certain size. If you wanted to know any more about any particular service connection you had to go back to the original permit.

So that this plan was gotten up, and on that page, which is a fair sample, it shows the exact location of the mains, the exact location of every hydrant, the exact location of every valve in feet and tenths of feet, and the exact location of every service connection, its age and size; and, in fact, everything about our system is in that book.

In talking with my fellow-superintendents in the neighborhood, a great many of them have objected to my system of records for the reason that perhaps it cost too much money, so that before I came away I looked up just what it did cost. We had wall maps on a scale of 440 ft. to the inch. Those wall maps, of course, would show which side of the street the main was on, and show which side of the street intersection the valve was on, but it was altogether too small a scale to show the details that we wanted. Matters of that kind we had to start with. Our city has 65 000 population, and that record is in 14 books, with 50 pages each, properly indexed. Each page is drawn on Paragon mounted drawing paper 18 in. by 24 in. upon a scale of 40 ft. to the inch, which gives plenty of space for all the notations required.

The property lines and reams of streets are shown in black and the mains and connections in red, and then the valves and hydrants in black. We cover 17 square miles of territory, we have 155 miles of mains, 1 342 hydrants, 1 362 valves in the mains, and 13 000 service connections.

Now, the entire record cost us to build $7 500, and it costs us to keep up, including the auxiliary valve books for the distribution force, and so on, about $1 200 per annum. It has cost $1 200 for the last few years for the reason that we have done a great deal more work than we ordinarily do. It would not cost us that much in normal years. So that I am going to leave these two papers here, and I should be pleased to have anybody who is interested in that line look them over.

I think that is all, Mr. President, that I care to say, except that there was a matter came up at the first meeting here, about charging for public use of water, and most of us — or, I think, all of us — were very much surprised to find that the Bridgeport Hydraulic Company do not get any revenue from the city of Bridgeport. We believe in our town we have that question solved, and solved right. In the first place, there is absolutely no question but what a charge for public use of water is the right principle. Right across the way from our water board office there is a very large foundry that pumps every drop of its water, — it does not pay us a cent for water, — and it is hardly fair for the water payers to pay for the fire protection on that plant.

In 1908 we had a citizens' water committee. By the way, Saginaw had been having citizens' water committees for a good many years, trying to get an improvement of the system. But that citizens' committee went into everything very thoroughly, — amongst other things the charge for this

public use of water, — and by agreement with the then board of water commissioners and the common council, and this water committee, and a citizens' mass meeting, we established the idea that the plant, although it is municipally owned, should be treated exactly as though it were a private corporation. In other words, the water department was told to take care of itself. We established a hydrant charge of \$45 per hydrant, a charge of \$250 per water trough, of which we had 40, and other charges for public use of water of all kinds, — the police department, fire department, parks, cemeteries, and flushing sewers, and so on, — until we got together a gross charge of about \$80 000, or a little over. Then we credited to the city $1\frac{1}{2}$ per cent. of the book value of plant in lieu of taxes, and we credited to the city a 4 per cent. interest as the city's equity in the plant, which meant that when it went into effect the plant was appraised at about \$900 000, of which there was \$450 000 of outstanding bonds. The other \$450 000 we called "the city's equity," and we give them credit for 4 per cent. of that every year.

There is another charge that we make. In our city nobody handles any money except the city treasurer, and we charge him with the interest on the daily average balances that he gets from the bank, and that amounts to some \$4 000 or \$5 000 a year. We most always have about one hundred thousand dollars or more balance.

So that we get net between \$40 000 and \$50 000 a year for public use of water, and our people have been so educated that that public use of water goes into our budget just as much of a standard item as the maintenance of the police department. We think we have solved the question with one exception, and that is that the prices prevailing now are the same as prevailed in 1908, and we ought to get more.

Discussion.

Mr. J. M. Diven.* Do you allow any credit for the city treasurer's work in collecting water bills?

Mr. Johnson. No, sir.

Mr. Samuel H. Mackenzie.† I have been much interested in Mr. Johnson's talk, both in regard to his records and in the fact that the water department is maintaining itself, which I believe is the correct principle. We have been running on that principle at Southington since the plant was taken over by the town, about ten years ago, and it has worked satisfactorily. When a correct form of accounting such as that adopted by this Association has been adopted by a water department it will help to bring that practice about.

* Secretary American Water Works Association.
† Engineer Southington, Conn., Water Dept.

It might be of great benefit, especially to the smaller departments, if an exhibit could be arranged for some of our conventions, in which the blanks in use by the different departments for their meter records, service-box records, gate records, and pipe locations could be brought together and arranged so that we could look them over and perhaps get some ideas that would help us in our work. To bring the matter before the Association I will make the following motion:

> The President is hereby empowered to appoint a committee to arrange for an exhibit of accounting forms and record blanks in use by the water departments and companies of this Association, provided the same receives the approval of the Executive Committee.

[Motion carried.]

THE CHLORINATION OF NEW ENGLAND WATER SUPPLIES

BY WILLIAM J. ORCHARD.*

[*Read September 14, 1921.*]

When the chairman of the Committee of the Water Works Manufacturers Association in charge of this evening's meeting asked for a title by which to designate this paper we are afraid that our sectionalism cropped out.

A New Englander by birth, training and education, whose first impressions while working with sample bottle or plumb-bob under the superior tutelage of Sedgwick, Goodnough and Foss have perhaps been colored by experiences following his emigration to other districts, may perhaps be pardoned for the local color of the data to be presented.

There isn't very much to say about "The Chlorination of New England Water Supplies," because relatively few New England water supplies are chlorinated.

Let us examine a few figures.

Nineteen hundred and ninety-six communities in the United States chlorinate water or sewage or both, with liquid chlorine. Only 128, or 6 per cent., of these are in New England. Twelve are treating sewage, leaving but one hundred and sixteen New England communities chlorinating drinking water. Nearly half, 43 per cent., of these are in Connecticut, where 51 communities use liquid chlorine to safeguard their water supplies; twenty-four are in Maine, eighteen are in New Hampshire, eleven in Rhode Island; Massachusetts has nine, while Vermont has three communities using liquid chlorine for their water supplies.

Scoring the states in this country in accordance with the number of communities using liquid chlorine, and starting with New York in first place with 254 and ending with Nevada in forty-eighth place with but one lone chlorinating community, we find Connecticut stands eleventh, Maine twenty-fifth, New Hampshire thirtieth, Rhode Island thirty-sixth, Massachusetts forty-first, and Vermont forty-seventh.

A manufacturer of chlorinating equipment naturally asks, Why this relatively small number of communities using liquid chlorine in certain sections of New England?

Now, in trying to answer that question, the speaker appreciates that he is skating on thin ice — dangerously near a deep hole labeled "The Johnsonian Controversy," and caution dictates that he skate the other way.

* Of Wallace & Tiernan Co., Inc.

But it is a fact that there is more resistance to the chlorination of drinking water in New England than in any other section of the country. Some of this is due to a firm, honest conviction in the purity and safety of unsterilized water supplies; some of this is due to complete deep-rooted faith in the absolute efficacy of storage and watershed patrol. But in the speaker's opinion the principal cause for this resistance to chlorination in New England is the marked aversion found in some quarters to the application of chemicals in any form to drinking water. It matters not if, as in the case of sterilization, a barrel full of chlorine will suffice for a Woolworth building filled with water, the objection is to the application of chemicals in any form — no matter what the chemicals may be. This attitude was clearly expressed by one of New England's most prominent engineers, who said to the speaker, "Up here, we don't want medicated waters."

We do not agree with the opponents of chemical treatment, but we have absolutely no doubt of their sincerity. We can only hope that they will believe that the rest of us are equally sincere as we try to persuade them to change their minds.

Boston, for instance, — or rather the metropolitan district, — is the only large community east of the Rockies that does not chlorinate its water supply as an added precaution.

But Boston points to its low typhoid records with justifiable pride — and takes the stand that perhaps other cities have to chlorinate their water supplies to obtain low typhoid rates, but Boston can get a low typhoid rate without chlorination, so "why put chemicals in the water?"

Of course, then comes the question of the potential danger of an untreated supply, especially where reservoirs are easy of access — but here again we approach the controversial, and turn the page — for such is not the purpose of this paper. But as though to compensate for some of its seeming neglect of the manufacturers of chlorine and chlorine control apparatus, New England has made many contributions to the development of the process of chlorination which the editors of the *News-Record* assure us in their current symposium has come to stay.

As time brings to light more facts concerning its nativity it seems more and more likely that the experimental work of Sedgwick and Phelps at the Massachusetts Institute of Technology in Boston,a score of years ago, was the corner-stone of our present practice in the chlorination of water supplies.

It was at Torrington, Connecticut, that Tiernan — then struggling with Wallace in the development of a practical ozone generator for the sterilization of water — worked with Phelps in checking a water-borne epidemic, made use of bleaching powder to sterilize the water supply and caused them to transfer their energies from ozonation to chlorination. It was at Stamford, Connecticut, that the first automatic chlorine control apparatus was developed, thanks to the patience and coöperation of the late and highly-esteemed manager of the Stamford Water Company, Mr.

E. L. Hatch, one of the earliest and always one of the stanchest supporters of chlorination.

The first recorded reduction in color obtained by treating water with chlorine was secured at Branford, Connecticut, by Minor, of the New Haven Water Company, where, under his patronage and with his keen interest, an entirely new type of equipment that holds great promise has been under test for nearly a year. It was at Exeter, New Hampshire, that Weston first introduced liquid chlorine to water before the coagulant in order to reduce alum requirements, a procedure that has now been adopted with success by many operators. And at the abattoir at Brighton, Massachusetts, liquid chlorine was first used to sterilize wash water used about the packing plant — a procedure that is now universal in the packing industry; while the Waterbury, Connecticut, Y. M. C. A. was one of the very first to use liquid chlorine to sterilize swimming-pool water.

So you see New England has a considerable responsibility for the position in which the process of chlorination now finds itself, and has contributed almost as much to this as it has to other developments in the field of sanitation.

There is much that New England still can do. We seem to be at a turn in the road where new standards of water are to be developed, or else new interpretations placed on existing standards. The symposium on chlorination in the current issues of the *News-Record* and Mr. Brush's article in the current issue of *Fire and Water Engineering* clearly points to some of the problems still to be solved. With the increased attention being given to the chemistry of colloids and to the electrolytic dissociation theory as exemplified by the interest in hydrogen-ion concentration, chlorination presents a wide field for study. And in that study the whole-hearted assistance of all New England water-works men is needed.

In New England, more than in all the rest of the country, are located the men who since the late eighties have guided the development of water-treatment to its present stage. Their help is needed in the developments that are to come. That help will speed the day of arriving at a proper appreciation of the merits of various modes of water supply protection.

REINFORCED CONCRETE PIPE AS APPLIED TO WATER-SUPPLY LINES.

BY W. G. CHACE.*

[*Read September 1, 1921.*]

My association with the Lock Joint Pipe Company is comparatively recent, but my association with concrete for the carrying of water is not quite so recent.

People generally speak of concrete, or think of concrete, as the proper material for foundations, to be built in place within molds, for bridges or for dams, or for any structure which requires mass and compressive strength. They probably do not as often think about concrete of a quality which will prevent the seepage of water, especially through thin walls.

In order to make possible the carrying of water long distances it became necessary to get a moderately inexpensive material and a permanent material, and, as you will recall, the New York Board of Water Supply chose concrete for the great bulk of the length of the conduit. They used it largely limited to the lower heads, — practically to heads where the pressure was that of a flow line. For their siphons they used steel pipe, cast-iron pipe, lined or unlined, but generally lined with mortar.

In the Winnipeg water supply we had a similar proposition. The distance was 97 miles. The capacity desired was 100 million gals. per day. The location was through a virgin territory, and over a country which was practically prairie. The application of concrete for the entire project was, it seemed to me, and it seemed to those in charge, quite reasonable. Thus not only were the horseshoe sections, of which there were 75 miles, built of concrete, plain or with some reinforcement, but the pressure lines up to 90 ft. head were also built of concrete pipe reinforced, 10 miles of which were built in the trench, the other 12 miles being premolded pipe, for which the designs of the Lock Joint Pipe Company were chosen.

Now, the requirements for the pipe were such in that 97-mile stretch that it became necessary to obtain a mixture of concrete that would be water-tight. I won't keep you any longer than to say that from tests of 22 miles of the pressure pipes in the Winnipeg systems — which tests were made by displacement — along with tests to full working level of seven "cut-and-cover" sections, altogether 1 400 ft. (200-ft. sections at different places in the aqueduct), the nearest estimate we could get of the loss of water from the conduit itself throughout the whole 97 miles was one half

* Of the Lock Joint Pipe Company.

of one per cent. I think no similar project that I have heard of can show such a result, and we were fortunate in that because of the fact that we were able to get a material for our concrete which, with only a barrel and a quarter of cement per cu. yd., was tight enough, from specimens taken, so that it would stand 90-lb. pressure per sq. in.

It is possible, therefore, to make pipe of concrete sufficiently water-tight at the beginning; and one of the characteristics of concrete, as most of you may know, is that water-tightness increases in such construction with age and use, no matter whether the water carries the material in suspension or whether it be absolutely free of material in suspension. A concrete pipe line, therefore, should be given credit for its condition at the end of the first year rather than for its water-tightness at the time of laying.

So much for water-tightness.

Generally speaking, compressive strength is not the final desideratum, or the outweighing desideratum, in such concrete, but, rather, impermeability without any more sacrifice of compressive strength than necessary. We ordinarily make a practice of using a very rich mortar, or rich concrete; mortar for some classes of pipe and concrete for others. If our sand be harsh, or if we have difficulty otherwise in getting a water-tight body, we have introduced colloidal material into the mix for the purpose of cutting down permeation, and with great success.

Three weeks ago, in discussing this matter with Professor Abrams at Chicago, he told me of experiments they had made with colloidal material, in which he had investigated the effect of the addition of such material to concrete mixtures, observing the effect upon the compressive strength, and he found that, generally speaking, addition of colloidal material up to 10 per cent. of the weight of the cement caused a loss of practically nothing. In other words, an addition of colloidal material of 5 per cent. might reduce the compressive strength by 5 per cent.

So that the obtaining of an impervious concrete in such a manner is quite a practical and is quite a reasonable and well-worth method of getting the results aimed at. In regard to the use of concrete for the retaining of water under pressure, our practice has not been carried beyond a 100-ft. head with the thin wall that we use. Smaller pipes than 15 in. have not been attempted by this company, although in some other areas they are being made. But the limitation of cost,—because such pipe must be made on the location where the pipe is to be used,—the limitation of competition, the matter of gross earnings, and a few things like that, caused us to choose 15 in. as the minimum dimension for which the reinforced concrete pipe is offered. We still continue those limitations, the considerations governing them being almost continuously uniform.

Up to 100-ft. head reinforced concrete as such—that is, a wall of concrete having buried within it a mesh or cage or bar reinforcement—is satisfactory, and we have been successful in using a wall thickness as

low as 3 in., with concrete which has been poured into the molds in liquid form. This does not apply to articles of concrete which may be made with a dry mixture, but it must be a wet mixture of reinforced concrete. When it comes to higher heads than that, we have adopted the principle of establishing in the wall a cylindrical water stop, that water stop being a thin sheet of steel, as has been used with success by some other companies both on this continent and in Europe. On this continent the American Pipe and Construction Company some years ago, under Mr. Ledoux, who is here, and some other gentlemen who have done a great deal of work in that connection, completed a goodly number of lines which are of the same nature in a sense, although not made in quite the same method.

In Europe, pipe of that nature has been subjected to heads as high as 500 ft., and in diameters up to 48 in. and slightly larger. The 500-ft. head is not taken care of as to its bursting stress by the steel sheet itself, but the reinforcement to enable it to stand the bursting stress of that pressure is placed in the walls of the concrete, in the European practice, both within and without the steel sheet; but, in our practice, on the exterior shell of the pipe, i.e., in the exterior shell of concrete enclosing the steel cylinder.

Now as to the characteristics of concrete pipe for water supplies:

The minor characteristics, such as sufficient strength and rigidity, are available in walls 3 in. and upwards in thickness.

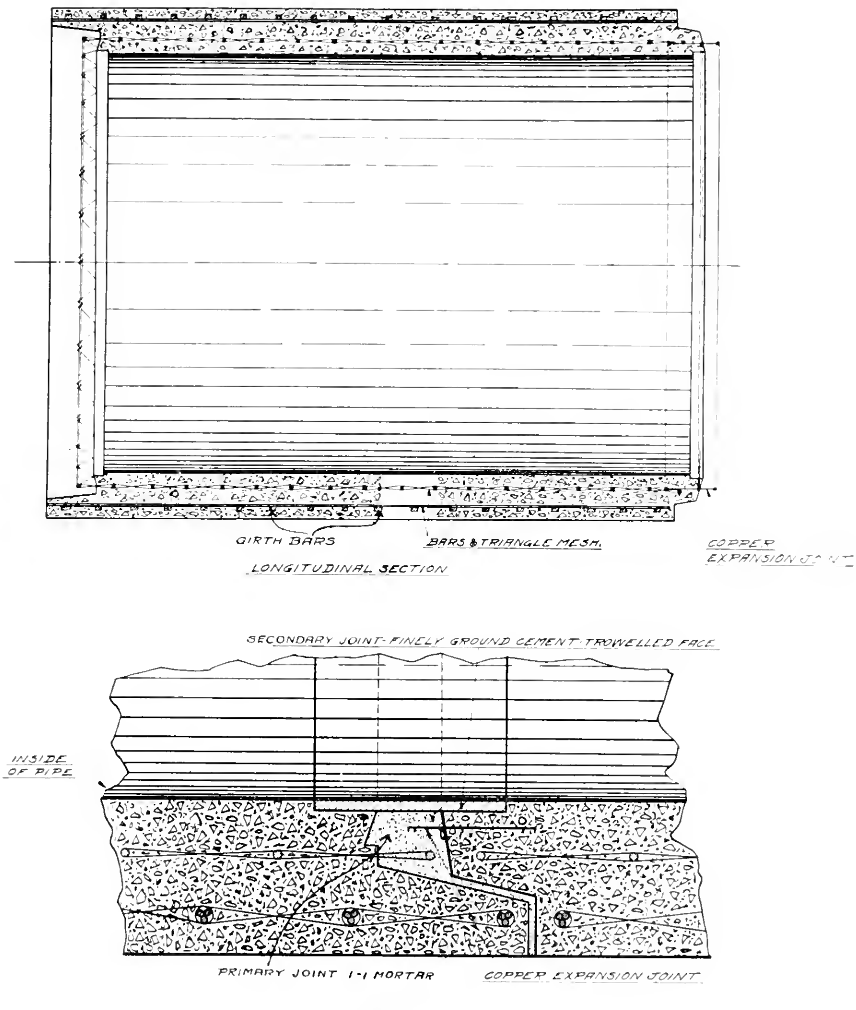
Water-tightness increases with age.

If the pipe be manufactured, as is ours, within steel forms which are kept sleek and clean, and true to dimensions, the interior and exterior of the pipe walls are smooth, and by virtue of the smoothness of the lining, pipe made of reinforced concrete has a very high carrying capacity, than which, I think you will find from the tests, there is no superior. The Department of the Interior at Washington, for instance, through their Mr. Scobey, issued not long ago a bulletin on the question of the carrying capacity of concrete pipe, to which reference may well be made. The results of the tests of one of the Lock Joint Pipe Company's lines is shown in that bulletin, and the coefficient of friction obtained. Our test on the Victoria line showed less than .011 as the value of n, which result could only be obtained by virtue of highly-polished, smooth interior forms.

The carrying capacity of concrete pipe obtains throughout its life. That is a very important feature in the carrying of pure soft water, particularly with soft water which contains no salts in solution. No tuberculation occurs. There is only one exception, and that is, if the water be from a lake there may be some algæ growth such as would be common to any pipe. But a party was telling me last week that the result of a test on concrete pipe in which there was an algæ growth seemed to show an increase in the carrying capacity. I could hardly understand that argument. My opinion would be to the contrary, — that the introduction of algæ

would slightly decrease the carrying capacity, but only to a small extent. It is easily cleaned.

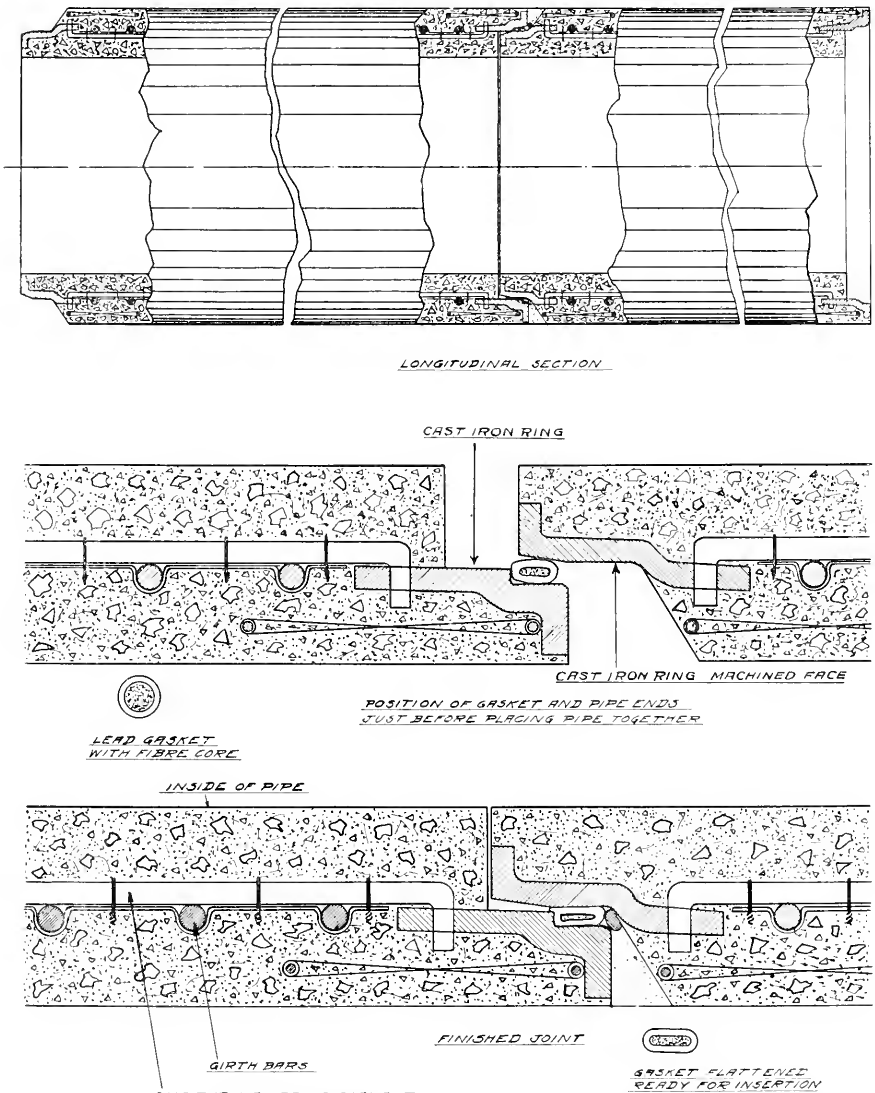
The reinforcement within the wall of a pipe is adjusted in a proper relation to the bursting pressure and to the earth load pressures, which



PRESSURE PIPE WITH COPPER EXPANSION JOINT

may apply to the location in which the pipe lies. We have made it a practice to modify that reinforcement by steps of, roughly, 20-ft. head, thereby gaining an excellent economy in the use of the steel. The reinforcement has in our practical work a low stress, — not over 12 000 lb. per sq. in.

That brings out immediately a very important fact in connection with reinforced concrete pipe for water supply, which is this: It is almost impossible in a well-built line to lose the ability to deliver the water to the terminus aimed at. A rise of pressure may split the concrete in such a



manner that water will seep through the wall along the crack caused by the rise in pressure, but parts of the concrete pipe wall will not be blown out. The pipe will remain a cylinder. Water may pass through the wall at the cracked section, where the heavy pressure may have hit the pipe,

but when that surge has passed, the reinforcement, by its elasticity, immediately closes the gap, and through the whole phenomena the water is delivered to the terminus aimed at. I have burst 66-in. pipe carrying two cylinders of bar reinforcement. It was designed for about 33-lb. pressure, and we had a pressure above 90 lb. when the concrete opened, and the water exuded the full length of the pipe section under test, but as soon as the pressure was released and the working pressure again admitted, there was no evidence along that fractured axis of losing water at the normal working pressure.

Now, your attention has been drawn chiefly to the question of the concrete in the pipe wall. The joint is a very important thing, and in most efforts to make concrete pipe for water supply lack of a proper joint design has been the limiting feature which has prevented some people from succeeding in that effort. Two types of joints have so far been utilized by this company. The first type, and the one which is still applied to pipes of diameters greater than 48 in., is the use of a copper ribbon buried half in the spigot of the pipe and half in the mortar of the joint between the spigot and the bell after the pipes have been laid in the trench.

For smaller pipes, in which the making of such a joint is unpleasant and difficult for the workmen, a slip joint has been devised consisting of a cast-iron spigot ring and a cast-iron bell ring, cast and molded right into each pipe section. Such pipe sections are ordinarily 12 ft. in length. These two cast-iron rings are secured together by longitudinal rods, which rods support the circumferential reinforcement in the shape of a cage. The spigot surface is finished in boring mills; the bell has cut within it a wedge-shaped groove in which is laid up an elastic lead-pipe gasket. The elasticity is provided by wicking made within the gasket. After filling with wicking, the lead pipe is rolled into an elliptical cross-section, and a hoop is laid up in the bell, after which the joint is made by forcing the spigot of the next pipe into that bell. The work is then complete, so far as the pipe laying is concerned, by that very process of forcing the spigot into the bell. That class of joint has proven under test to be a very efficient, water-tight joint, and one which is capable of taking care easily of all the changes in length due to the temperature variations in the water, and also of settlement, such as ordinarily takes place in the ground under backfill, or under certain foundations,—that is, not too perfect foundations, as one sometimes finds in trench work.

Discussion.

Mr. Allen Hazen.* We first used reinforced concrete pipes at Toronto, Canada, in 1909. The business was comparatively new then. On this work we had the materials of concrete on the ground, while iron pipe was somewhat more expensive than in the United States and the financial advantages of using concrete pipe were considerable. The pipe itself was very satisfactory. There was difficulty in getting the joints completely tight, and in fact they were never made entirely tight, but they were sufficiently tight to be reasonably satisfactory in the service where they were used. The heads were very small, — I think not more than 6 or 8 ft. in any case.

The pipe at Victoria, British Columbia, interested me very much. I had the pleasure of seeing it about the time it was finished. The joints at Victoria were similar, I believe, to the Toronto joints. It did not represent up-to-date practice. The interesting methods that Mr. Chace has described to us were not available at that time. The Victoria line was very far from being tight.

There was another interesting thing about this Victoria pipe. When it was laid, the interior was as smooth as glass, as Mr. Chace has told you. It was the smoothest pipe of any kind that I ever saw, and the quantity of water that passed through it was so high as to almost break the records for coefficients. Mr. Rust measured the water, and I cross-examined him very carefully as to his methods, to make sure that no error had been made, and I have no doubt of the substantial accuracy of the reported results. But the smooth surface did not last. After the pipe had been in use for a short time there was a great reduction in carrying capacity, and the coefficient came down to a very ordinary rating.

Mr. Rust wrote me that the smooth interior surface of the pipe had become quite rough. He thought this was caused by the free clay used in the cement, that was probably rather easily eroded by action of fresh water, even with slight velocity, and he thought that the removal of the clay probably loosened the particles of cement and hence honeycombed the pipe lining. In view of subsequent experience, the Victoria coefficient of discharge, obtained when the pipe was new and published as Mr. Chace has stated, is not a safe one to follow.

Mr. Theodore R. Kendall.† I would like to ask Mr. Chace how they make the curves in this line, other than the ordinary curves. Did you make them in the joints?

Mr. Chace. Generally speaking, the curves are made of small degree, or of large radius, by simply springing each pipe joint slightly. If they are of smaller radius they can be made with the copper joint by shortening the pipe on one side. This will alter the diagonal diameter

* Consulting Engineer, New York.

† Engineering Editor, *The American City*.

of the pipe. That brings together faces which are not absolutely alike, but the cross-sections are so nearly the same that they matched very well. On sharp angles we made the practice of building into monolithic joints. That takes care of the three conditions met with.

As regards the Victoria line, that line is probably exposed to the most severe conditions that any concrete line was ever asked to handle. It lies in an open trench in the side of the mountain. There is no backfill over any material portion of it, and it is subject to very great ranges of temperature every day. When it was built, it was built without any expansion joints or water stops at the joints.

The style of construction to which Mr. Hazen refers is the lock joint, such as we use in our sewer construction, where the bell reinforcement overlaps that projecting from the spigot end and the mortar joint seals both together. That class of construction had been utilized in water-supply lines only in the very earliest of our practice and for low heads. We offered to the city of Victoria at the time the use of a copper expansion joint, and recommended it, but it was a question of cost to them and was not accepted. Now, the line is not always running full of water. It is a flow-line conduit except where it crosses valleys, and only occasionally is it running full. A recent inspection by our president, and by engineers who have seen it, indicates that about 200 odd joints in that line are the ones through which nearly all of the loss of water is occurring in low temperatures. The quantity of water available is ample, the quantity delivered is ample, and the engineers in charge of it have expressed no concern, and have told us not to bother about it at all, as they would take care of these joints when necessary. It is a small matter to correct the situation by means of plastic material.

As to the roughness to which Mr. Hazen refers, I think that is a question of local experience solely. We have not run across it, to my knowledge, in any other water supply.

The information as to the coefficient of friction is from the report by Mr. Scobey, of the Department of the Interior. I do not think the test was made as soon as the line was completed.

Mr. G. A. Sampson.* I would like to ask about the steel cylinder in the high-pressure pipe, — as to the thickness of it, how far it is imbedded in the second sheet of concrete, and as to whether it is combined with the reinforcement or not.

Mr. Chace. The steel cylinder is a new development. We believe thoroughly in the principle that no corporation or no idea can live unless it is growing, and we have been trying to enlarge our scope and improve our methods, and this is the latest step that has been taken in the expansion of the field of the application of reinforced concrete to water-supply lines.

The steel cylinder is designed as a water-stop primarily. The question came to us when we put it in, whether we should put all our reinforcement

* Of Weston & Sampson, Boston, Mass.

in that cylinder or only such of it as would make a cylinder practical to work with. A gage of 24 or 26 would be too light to handle and make a practical working unit of it. On the first job we used gages of 14 and 12. That was on a 36-in. line. I think our practice would be to not go to heavier gages than No. 14.

The cylinders are electrically welded together. A sheet is rolled into a cylinder, and then a longitudinal seam is run by an automatic electric welder. We are able to develop a very large proportion — it has tested as high as 100 per cent. — of the strength of the sheet.

The additional reinforcement over and above that is placed in the exterior shell. That reinforcement is not secured to the cylinder, but is secured within the outer wall upon longitudinal ties from bell to spigot end. We desire to keep this reinforcement distant from that cylinder so as to embed it thoroughly in the mortar of the exterior shell. The cylinder itself is secured to the cast-iron rings.

MR. J. W. LEDOUX.* The inside shell is probably quite as satisfactory to use as a reinforcement as to depend on the ordinary reinforcement, because the price of an iron in that shape (sheet) is usually about double what the price of reinforcement iron is. I think that must be the only reason why that can't be used as the complete reinforcement for the pipe.

MR. CHACE. No; there is another very practical reason in production, Mr. Ledoux, and that is this: Automatic electric welding can be done on a thin sheet at a higher speed than on a thick sheet; also, the additional steel placed in the exterior shell is by far the most economical and therefore that combination is the proper construction.

---

* Consulting Engineer, Philadelphia, Pa.

PIPE JOINT COMPOUNDS.

Discussion.

[*September 14, 1921.*]

Mr. Michael F. Collins.* There are compounds before the water-works superintendents to-day called leadite, hydro-tite, and metallium. I would ask the superintendents who have used either for any number of years what their opinions are about it, and what results they have obtained. It is something, I think, that is worthy of consideration of everybody here to-day.

Mr. J. M. Diven.† With the long record and a long experience with lead joints, which have proved very satisfactory, the speaker was slow to try any substitutes, nevertheless watched the development of leadite, the first one brought to his attention, and its use by others; with so many successes and the time test demonstrated, did finally try it. The first use was on a rather unimportant line, and where the pressure was low. The success with this induced further trials, and all were equally successful. The final test was the pouring of a joint for a 30-in. double tapping sleeve, two 8-in. outlets. This work was done in the spring, when the temperature of the water was rather low, and was made with the pipe line in use. The consumption, all passing through this line, was from 15 000 000 to 18 000-000 gal. per day, indicating a velocity of nearly 5 ft. per second, which would keep the pipe cool. The joint was successfully poured, the two taps made without starting any leak. The pipe line was under about 110 lb. pressure at the time.

A little more care is required in melting leadite than is the case with lead; however, little trouble was found in training men to its use.

Mr. Collins. I should like to learn the life of these substitutes for lead. I know cases where a compound has worked very well; in my own case I have used some where I have had good results. But lead has been in use for hundreds of years, and whether substitutes are going to stand the test of time, or whether they will injure the spigot or bell end of the pipe, is something I should like to know.

Mr. Lincoln Van Gilder.‡ I can't tell anything about how long it will go, but I know that it has gone nineteen years. Mr. Hawley left the company with which I am now connected in June of 1902, and he

* Superintendent, Water Works, Lawrence, Mass.
† Secretary, American Water Works Association.
‡ Superintendent, Water Works, Atlantic City, N. J.

poured the leadite joints previous to leaving Atlantic City. Those joints are in perfect condition to-day. We have used leadite almost exclusively for fifteen years, and it has always proven satisfactory.

Mr. Diven. I think Mr. Hawley was about the first user in the country.

The President. He was the first I knew of. The fact that men like Mr. Hawley and Mr. Van Gilder are keeping on with it speaks well for it

Mr. George F. Merrill.* Have you had any experience with leadite on steel pipe, or pipe of that kind?

Mr. Van Gilder. We have had a little experience with that. In connecting up large meters and putting in cast-iron pipe, it is our regular practice to take a wrought-iron pipe with one end threaded and insert a blank end in the bell of the pipe for the leadite, and that holds perfectly, just as in the cast-iron pipe.

Mr. Diven. While on that subject, I might tell Mr. Van Gilder a better trick. Take a threaded end and put a coupling on and insert the coupling in the bell end. You have more strength and less lead.

Major Leonard S. Doten.† About two weeks ago, in making connection between 6-in. iron and cement pipes I took a chance. Ordinarily, we have a lot of trouble in pouring the lead in there in making the cement keep the lead in place, but in this case it worked fine. We completed that particular piece of work and had the hole filled up inside of two hours.

Mr. Carleton E. Davis.‡ Has Mr. Van Gilder used the leadite up to 48 in.?

Mr. Van Gilder. No; we have not used leadite on larger than 24-in. I might say to the members that on our large lines we prefer lead.

Mr. Davis. I have poured up to 60, but I don't know whether they are going to work or not. It is said frequently that leadite is more difficult to handle than lead in case of heavy vibration, like that near a railroad track.

Mr. Van Gilder. We have had no more trouble than with lead in those cases. The leadite is as easy to repair as the lead.

Sect. Gifford. Mr. Van Gilder, suppose you have a leak where the joint is improperly poured, or seepage around the entire joint, and it is a place where you can't draw off the water to clean the pipe; how is the repair made?

Mr. Van Gilder. I can explain that by taking a case of this kind, which we sometimes meet and accomplish in this way: You all know how difficult it is to cut off a section of old pipe and get it absolutely tight, and also the danger in pouring the joint with lead if there is any seepage. In this case we do not take the time to go and open our valves, but in making up the last joint we put the joint ring up, so that the leakage from any part

---

* Superintendent Water Works, Greenfield, Mass.

† Advisory Engineer on Sanitation, War Department, Washington, D. C.

‡ Chief Bureau of Water, Philadelphia, Pa.

of the pipe will pour from right under the plate ring, then we pour the leadite in from the top. Frequently it will pour solid, but if it becomes spongy at all there is too much water, and we take it out and pack it in either with lead wool or leadite to make the joint perfectly dry, but still the water is running.

Mr. R. H. Ellis.* Under what pressure would you be able to use leadite?

Mr. Van Gilder. Forty pounds normally. That is the highest I have tried.

Mr. Ellis. I have myself tried the experiment of calking up some small holes with lead wool. In my own case it did not work very satisfactorily, but it was under 140 lb. pressure.

Mr. Van Gilder. It is entirely safe for the workman to pour leadite molten right into water. It does not make steam of an explosive force. It pours at about 350°. You can pour it in the wettest joint you have got.

Sect. Gifford. There is one other question that I am interested in, and that is the experience of the members who use substitutes for lead in electrical thawing. I think I was told at one of our winter meetings that substitutes for lead were non-conductors of electricity. I was also told that there was 23 per cent. of iron filings in one of the compounds, and it ought to be a conductor. I have just finished laying about 8 000 ft. of pipe, mostly 12-in., and used leadite on most of it, but inserted a lead wedge in every joint. I am not afraid of electrolysis — I don't have any — but do want to thaw by electricity if it becomes necessary. I should like to know if it is possible to thaw without the lead wedge, or some similar substance to carry the electricity.

Mr. Samuel E. Killam.† In addition to wooden joints, there are two joints in the Metropolitan Water system where we use a substitute for lead. These wooden joints leaked in winter on account of the contraction of the pipe line, and we tried hydro-tite. The first few days they leaked considerably, and I had my doubts whether it would ever take up, but in two months they were entirely tight. The wooden rings were left in between the bell and spigot. In testing these joints for resistance to electric current after the hydro-tite was poured, it was observed that there was considerable resistance in the material.

President Sherman. In your case, as I understand it, you had a wooden ring between the bell and spigot, so that there was no contact between the bell and spigot?

Mr. Killam. Yes, the wood ring was left in place and hydro-tite substituted for wood staves for remainder of joints.

Mr. Merrill. I wonder if any one has any information on leadite joints that have been laid for several years. I have been informed that after a year or two the conductivity increases quite considerably, — that

* Superintendent, Board of Public Works, North Andover, Mass.

† Superintendent Metropolitan Water Works.

as the rusting takes place it makes a good deal better conductor. I think that age has something to do with those joints.

THE PRESIDENT. Mr. Killam, were your joints very nearly new when you tested them for your electrical resistance?

MR. KILLAM. Yes.

MR. VAN GILDER. Leadite was poured in 1914 on a 20-in. line, about 10 000 ft. long. That would give age enough, I presume, to properly answer the question. We could test that quite easily.

MR. PATRICK GEAR.* The only experience I have had with leadite is this: My predecessor bought 100 lb. of it in 1910 and we experimented a little with it, but couldn't pour it just right. The man selling told us the great advantages of the stuff, and I asked him if he could pour a joint that would be watertight in twenty-four hours. "Sure!" he said. We had him pour two or three joints, and I let the water on when he told me to do so. It sprayed all around. I left it there for twenty-four hours, and it was still spraying. It stayed there for a week and it was still spraying. I said I couldn't afford to use that stuff and then wait for a week to see whether it is good or not, because when I use lead I cover it up before testing it at all.

Another young man came along, selling leadite, and telling me the great merits of it. I asked him if he could pour a joint and make it come out successfully, and he said that he surely could I let him pour three or four joints. We let the water on after a short time and it burst out all around the room. He left in the course of three or four days, and I haven't seen him since.

They have not poured a joint successfully yet, so that I have not bought any more.

SECT. GIFFORD. I will send you up one of our laborers.

MR. GEAR. He will be a failure like the rest of them, I am afraid.

Another gentleman came along a year ago who had a substitute for lead which he called by another name. He poured four or five joints and they were fairly good, but there was nothing that would give me faith enough in it to make me pour a joint under a railroad track and cover it up.

MR. DIVEN. What pressure did you put on in your test?

MR. GEAR. City pressure; 85 to 100 lb.

---

* Superintendent, Water Works, Holyoke, Mass.

STEAM BOILERS.

BY F. W. DEAN.*

INTRODUCTION.

At the present time, more than ever before, it is of the greatest importance to carefully consider the most economical type of boiler and engine. In all parts of the world, even in coal-producing countries, the price of fuel as well as of all other requirements is abnormally high, and the types of boiler and engine that will give the most efficient performances without objectionable features should be sought and used. Greater care should be taken in firing boilers, as by care much coal can be saved, but I find increasing indifference to this by firemen.

It seems to me that there are more notions and superstitions abroad concerning boilers than about any other common thing.

The general design of a boiler is of less importance than is commonly supposed. If a boiler has sufficient heating surfaces so arranged that the hot gases circulate through or about them, if they divide the gases into thin streams, if the admission of air for combustion is at the right place, if the leakage of air into the gases where it does no good and cools the boiler is substantially prevented, if the surfaces can be cleaned and the fire box and grate are such that the combustion is good, the boiler will do well. Evidently these requirements admit of an infinite number of arrangements of parts. A " good steaming " boiler is almost any kind of boiler that is amply large for the work to be done. As generally used, the expression " good steaming " is meaningless.

The idea is commonly held that there is special virtue in radiant heat. The absorption of such heat merely extracts it from the hot medium, and if it were not at that time removed it would be available for absorption elsewhere by direct contact with the boiler-heating surface, and with equal value. If a fire box had no surface which could absorb radiant heat and a proper amount of surface which could absorb it by contact, the effect would be the same. The surface which has the opportunity to absorb radiant heat is usually that which deals with the hottest gases and for this reason is more active in absorption than any other surface. For these reasons it should not be supposed, as it commonly seems to be, that radiant heat is something that would be lost if there were not surfaces present to absorb it.

* Of Wheelock, Dean & Bogue, Boston, Mass.

Definition.

A boiler consists of two fundamental parts, a furnace for burning fuel and producing heat and a part containing water and absorbing heat. The furnace can be arranged for burning coal by hand firing, or by mechanical stokers. In either case, the coal should be burnt as perfectly as possible in order to economize, and it is possible with either to admit too little or too much air. Combustion is a chemical process, and should so occur that the product of combustion will be carbonic acid, and the quantity of this gas can be ascertained by an inexpensive and easily used piece of apparatus. The presence of a boiler with a furnace is not necessary for the proper combustion of coal. The function of the boiler is to absorb the heat after it is generated, and it should not be so formed or placed that it will, to any material extent, or at all, interfere with the chemical process of combustion. From this it is evident that there may be many different ways in which the surfaces of a boiler may be arranged. It depends somewhat upon the coal whether a large space is needed for good combustion, but it can be said that for coal with a small quantity of volatile matter, not much space is required. For example, a locomotive or a Scotch marine boiler will give most excellent results, although there is not much space for combustion, and the water-containing parts of the boiler are near the fire. These results plainly show that the idea that large space is needed for combustion, except with pulverized coal, and oil, which are moving fuels, is a mistake. If the air is admitted in the right quantity at the right place, good combustion will result, even if a relatively cold boiler shell is in close proximity.

In the case of bricked-up boilers, large fire chambers result in opportunities for air leakage, and such air seldom. if ever, enters where it aids combustion. What it in fact does, is to cool off the boiler and make a demand on the chimney which results in a waste of its capacity, and, if economizers are used, to diminish their effect.

Internally and Externally Fired Boilers.

In one respect boilers are divided into two general classes, known as internally and externally fired. The locomotive type, vertical fire tube, and Scotch boilers are called internally fired because the fire box and grate are within the boiler. The common American horizontal return tubular boiler and many others having the fire box below the boiler, or in front of it and not structurally a part of it, are called externally fired. Internally fired boilers have the advantage of having little or no brickwork, the latter being always a source of trouble. They do not permit air to leak in and cool the gases of combustion, and thus reduce economy and make great demands upon chimney capacity. A considerably larger quantity of air than is usually permitted to enter a boiler fire box is often desirable, but it should enter only where it aids combustion.

Fire-tube and Water-tube Boilers.

Besides internally and externally fired boilers, there is another division of types, known as fire-tube and water-tube boilers. In fire-tube boilers the fire passes through the tubes and the water surrounds them, but in water-tube boilers the fire passes around and between the tubes, and the water is inside of them.

The water-tube boiler was devised for the purpose of preventing explosions at a time when the shells of fire-tube boilers frequently exploded. It was an attractive idea to have the water confined in small tubes which probably would not explode, and which, if they did, would do relatively small damage. Unfortunately, water-tubes boilers consist of headers and drums as well as tubes, and of them there have been some very serious explosions, and tube explosions are common occurrences. Explosions of fire-tube boilers are now virtually things of the past, and were almost entirely caused by the use of lap longitudinal joints. The tubes of such boilers never do anything worse than leak. In most of the states of the United States lap joints are prohibited by law.

There is a great variety of water-tube boilers. Some consist of headers made in various ways, one at each end, connected by tubes. The headers are connected to one or more drums above. The tubes are always inclined, sometimes highest at the front end and sometimes at the other. The headers are frequently inclined so that the tubes are at right angles to them. Occasionally the headers are vertical and the inclined tubes enter small inclined surfaces pressed in the headers.

Sometimes the drum runs from the front to the back header, and sometimes it is placed above the lower header and parallel to it. The latter are known as "cross-drum boilers," and in my opinion are superior to the other, because the drums receive the steam uniformly from one end to the other, in small amounts per unit of length, and the feed water is supplied more evenly to the lower header. They carry the water better than the longitudinal drum boiler, show a truer water level, and are more likely to produce dry steam.

The headers of the water-tube boilers described are sometimes made of steel plates, two for each header, connected together in some manner at the edges. One of the plates is called the "tube plate" and the other the "hand-hole plate." The tubes are expanded into the holes of the tube plates and project through the plate about half an inch, this projection being bell-shaped.

The plates of the plate headers are usually stayed together by screwed staybolts headed over. The stays should have small holes drilled from each end to a depth of at least one-half inch beyond the inner edge of the plate, so that, if they break, steam and water will escape and cause the rupture to be known. These holes are often $\frac{3}{4}$ in. in diameter entirely through the staybolt, and those that are not utilized for tube blowing are plugged with metal plugs, of which there are a number of kinds.

It is necessary to close the holes in the hand-hole plate, and this is done in various ways. Each hand hole is usually just large enough to allow one tube to pass through, but sometimes, if the tubes are small, it is large enough for four.

Other boilers have the headers formed of vertical rectangular boxes, each wide enough for one vertical row of tubes, closed at the lower ends and placed side by side, touching each other. The tops of this kind of header are connected to the drums by means of short pieces of pipe called "nipples", which are expanded in holes in the top of the header and the bottom of the drum. Plate headers are usually flanged and riveted to longitudinal drums, but to cross-drums they should be connected by means of expanded nipples. Boilers with narrow header boxes are likely to allow air to leak in between them, and the spaces between them must be calked with a suitable material; but, nevertheless, they are likely to leak.

Workmanship.

Good workmanship on boilers is frequently mentioned but it is not so well understood. It consists in having the rivet holes drilled and exactly matched in the adjoining plates, rivets filling the holes, and plates in contact, or so near it that a steel feeler 0.003 in. thick cannot touch the rivet when slid in between the plates before they are calked. If staybolts are used, the threads should fit tightly and the heads be well formed. Tube holes should not be too large, so that it will not be necessary to expand the tubes too much. The difference in diameter of holes and tubes should not exceed $^1/_{32}$ in. Tubes should be neatly beaded and should not crack by beading. Care should be taken to curve the plates and butt straps accurately to the edges. The heads of rivets should be central with the rivet shank, with a maximum error of $\frac{1}{8}$ in. There are many things to be considered in addition, but it is hardly worth while to mention them here.

Baffles.

The baffles of water-tube boilers are means of dividing the spaces among the tubes into passages for the circulation of the hot gases, in order that the tubes may be well swept by the gases and have an opportunity to absorb the heat which they contain. The baffles are sometimes at right angles, or nearly so, to the tubes, and sometimes parallel to them. I prefer the latter method because the baffles are then simpler and more durable than the others, are more likely to be gas tight, and can be more easily applied and renewed. Besides this, the gases more completely sweep the tube surfaces, and by the use of hollow staybolts in connection with them, soot blowers are more easily applied and permit blowing parallel to the tubes, which is more effective than blowing at right angles to them, this being necessary when vertical baffles are used. Boilers with transverse

baffles cause the gas from the fuel to move in parallel vertical streams, and those streams having an excess of air have little chance of meeting those with combustible gases, and burning them, as is the case with boilers having horizontal baffles.

Experiment shows that horizontal baffles can be made of steel plates, except on the lower row of tubes. The plates will usually touch the tubes on top and bottom, the tubes thus conducting heat from the baffles and promoting their durability. The advantages of steel plate baffles are that they have fewer openings between them than tiles to leak gas, do not crack and get out of place, are thinner, and thus enable a boiler of given dimensions to have more tubes than when tile baffles are used.

In designing horizontal baffles the tendency is to make them too short in order to provide sufficient area of gas passage between their ends and the headers. Measurements of the drafts and velocities in the passes and between the baffles show that the gases pass very close to the ends of the baffles, so that most of the space between the ends and the headers is useless. The same thing is shown by baffles placed in a wide, shallow stream of water. By placing oil upon the water it will be plainly seen that the water passes close to the ends of the baffles and the water in the remaining space is stagnant.

In horizontal baffling the lowest baffle should always be on the bottom row of tubes, for otherwise there will be tube surface under the baffle which is inactive and useless. Similarly, the highest baffle should be on top of the highest row of tubes instead of under them, in order to render these tubes efficient. The lowest baffle should always be in contact with the front header, for, if not, any air that enters the fire door of hand-fired boilers passes up in contact with that header, cools the boiler, and does not support combustion. This is true to some extent when stokers are used, for the hopper may not be full of coal, thus giving air passage, and when it is, the air passes through the interstices of the coal above the combustion level. Boilers with vertical baffles always have this defect, and this is another reason for preferring horizontal baffles.

By making the baffles longer, the gases are compelled to sweep over more of the tube surface, and this increases the economy and adds somewhat to the forcing capacity of the boiler. By the latter it is meant that the economy is well maintained when the fuel consumption is increased well beyond the intended rate, or, in other words, the efficiency curve is straighter than in the case of a boiler with short baffles.

Still further, the economy and forcing capacity are improved by increasing the number of baffles, and thus the number of passes, and the number should be made as great as is consistent with a practicable loss in draft, for the greater the number of passes the greater is this loss. Many boilers with horizontal baffles have only one at the bottom and one at the top, but such boilers would be more efficient if more baffles were used. If

it were possible it would be best to have a baffle on every layer of tubes, but the draft absorption would be too great and cleaning impossible.

In the case of a water-tube boiler with headers and straight tubes, as before stated, baffles at right angles to the tubes are frequently used, and of course the gases move nearly at right angles to the tubes. The greater the number of passes, the greater is the economy and the greater the capacity of the boiler to stand forcing beyond its rated power without greatly diminished economy, as in the case of boilers having baffles parallel to the tubes. Many boilers with transverse baffles have large spaces between the tubes and baffles and thus allow gas leakage and loss of economy.

In both kinds of water-tube boiler the gases make every effort to short circuit, or, in other words, to avoid passing into corners or parts of the boiler where there is the least obstacle. This is not only proved by draft and temperature measurements, but can plainly be seen by providing inspection holes in the sides of the boilers. Where there is no flame, sparks show the paths of the gases.

Water-tube Boilers with Bent Tubes.

Besides the water-tube boilers already noticed, which have straight tubes, there are those with drums and bent tubes, and no headers. These boilers are made in various ways, the simplest having two drums, one above the other, and parallel to the front, connected together by the tubes.

Another form has one drum at the bottom and three at the top, parallel to the front, the latter being connected with the bottom drum by bent tubes, and the upper drums connected together by such tubes. Another has one drum at the bottom and two at the top. Still another has two drums at the bottom and five at the top. In fact all tastes can be satisfied.

Still another well-known form is that having two drums at the bottom and one at the top, all at right angles to the front. The tubes run from both bottom drums to the top drum and the grate is between the two lower drums. This boiler is used chiefly in marine service.

Boilers of the above types have no hand-hole plates.

Methods of Closing Holes in Hand-hole Plates of Water-tube Boilers.

In the header type of water-tube boiler the hand holes can be closed by means of plates and gaskets secured by means of yokes and bolts. Each plate may cover one tube, or as many as four tubes if the latter are sufficiently small. It is customary for one plate to cover one 3-in., 4-in., or 5-in. tube, or four 2-in. tubes. A more modern, and, in the opinion of the writer, a better method, is to close each hole with a pressed steel tapered plug or cap, inserted from the inside. This requires no gasket, and is easily inserted, removed and re-inserted. It seldom leaks, and if it does it can be pulled in a little more and made tight.

Circulation in Water-tube Boilers.

Much has been written about circulation in water-tube boilers, but it is sufficient with few exceptions. It is important in such cases that the water should be freely supplied to the tubes and that sharp angles should be avoided unless the water is supplied from a large volume in which the velocity is low. It is, in fact, an important principle, that, of all parts of a water-tube boiler, the tubes themselves should have the least area for water passage, so that the entrance to the tubes and their exit should be unimpeded.

In the header type of straight-tube water-tube boiler, the most active circulation is through the lowest row of tubes and moves from the lower to the higher header. The circulation diminishes in this direction in the tubes above until near the middle row it is slight and may be in either direction. Above these the circulation is in the opposite direction to that in the lower tubes. This has been clearly shown by propellers in the tubes, the shafts of which pass out through stuffing boxes in the hand-hole caps opposite the tubes, the rotations being registered by an electrical device. The above refers particularly to cross-drum boilers, but in boilers with longitudinal drums the water in all of the tubes may sometimes move in one direction, and the return may be through the drum.

The boiler in which these circulation measurements were made was one having inclined headers, and the front header lower than the rear. The drum was parallel to and above the front header, to which it was connected by means of a pressed steel collar, in the limits of which were holes in the bottom of the drum for connecting the water space of the header with that of the drum. The feed water was distributed longitudinally in the drum and descended into the header. The top of the rear header was connected with the drum by means of tubes, and these served to carry the steam made into the drum.

Circulation nearly always takes care of itself, and while some boilers appear to be designed to prevent circulation, it takes place, nevertheless.

Steel Casings.

Water-tube boilers are frequently enclosed in steel casings, and always in marine work. This is a good thing and keeps the brickwork in good condition on the outside, and was originally done in land practice to prevent air leaks through the brickwork. It does not succeed in accomplishing this as it is found by piercing the casing and brickwork with observation holes, that jets of air can be seen burning in the boiler gases as they enter from the brickwork in various places. The air finds its way under and behind the brickwork from the ash pit, and enters the fire at numerous points.

Drum Heads.

A great number of heads of the drums of water-tube boilers have blown out and caused disastrous explosions. This is usually, and perhaps always, caused by cracking and erosion at the flange angle of the heads, which is probably reduced by the breathing of the heads with variations of pressure. If the material is somewhat cracked by the breathing action, the corrosion will be accelerated. Otherwise there is no more reason for corrosion at this point than elsewhere. In consideration of this defect of drum heads I have for some years advocated staying-drum heads, made in the customary manner, by means of gusset stays, as if they were flat plates. I consider drum heads with the convex surfaces inward safer than when outward. According to the Code of the American Society of Mechanical Engineers, such heads can be used if they are made of sufficient thickness.

Steam Pressure.

There is no difficulty in making water-tube boilers to carry any ordinary pressure up to say 300 lb. or 400 lb. per square inch or even more. Tubes with pressure inside of them will, of course, stand any pressure desired without being thick, and, in fact, they will not be of much thickness even if used to carry higher pressures than have been used. This is particularly true if the tubes are small, — say, 3 in. or less in diameter. A trouble, however, comes from the failure of tubes, from dirt, and this occurs in all water-tube boilers.

There is no ordinary limit to the holding power of tubes when expanded into headers or drums, especially as they always project through headers or drums about $\frac{1}{2}$ in. and are made bell-shaped.

In regard to drums, if they are pierced by as few tubes as possible and the longitudinal joints kept away from the tube holes, the drum can be made sufficiently strong to stand any probable pressure. As for the drum heads, there is no ordinary limit in pressure. While for large boilers, drums are frequently made 60 in. in diameter, it is my opinion that no boiler, however large, requires a drum of more than 48 in. in diameter, and seldom as large, especially if the boiler is of the cross-drum type, unless a large drum is necessary to accommodate tubes.

Sizes of Tubes of Water-tube Boilers.

In water-tube boilers for land service, the diameter of tubes range from 2 in. to 4 in. In my opinion, they should not in general be larger than 3 in., for I fail to see anything gained. By the use of 4-in. tubes the boiler is larger for a given capacity than with smaller tubes, and the gases are not so effectively subdivided. The length of tubes has a bearing on the diameter, and the limit of length for a 3-in. straight tube may be said to be about 20 ft. I think that the experience of many engineers during the late

war with marine water-tube boilers will affect their opinion, and that boilers of the marine type with comparatively short tubes of 2 in. to 3 in. in diameter will be more commonly used for land purposes than heretofore.

I fail to see any reason for having the tubes more than one inch apart, for this distance gives excellent service with all kinds of coal, or with oil fuel.

Method of Taking Steam from Boilers.

Experiment shows that the best method of taking steam from boilers is through the perforations of a pipe with closed ends, along the top of the drum and shell. The pipe should be as close to the top as possible and perforated along the top with holes not exceeding $\frac{3}{8}$ in. in diameter, uniformly distributed from end to end. The aggregate area of these holes should be such that the velocity of the steam shall be fully 8 000 to 10 000 ft. per minute. When this arrangement is carried out the pipe acts as a steam separator, as has been amply proved by tests. The steam nozzle should be in the center of the drum, so that the steam shall be drawn equally from all parts. The safety valve should never receive steam through the perforated pipe.

Boring the Insides of Tubes of Water-tube Boilers.

There are several kinds of tube borers that are specially made for boring out the insides of tubes and clearing them of scale, and such apparatus should be furnished with the boilers. For boilers having bent tubes expanded into drums, borers are so made that the operators are not required to enter the drums.

Fire-tube Boilers.

Although much of this paper has been devoted to water-tube boilers, it should not be inferred that fire-tube boilers are not meritorious. On the contrary, they are in most respects equal or superior to water-tube boilers. As high pressure as is usually desired can be carried on them, and when built according to modern requirements are safer than water-tube boilers, as can be readily shown by the records of explosions. The chief factor in making them safe, as before implied, is the use of butt longitudinal joints.

The American Under-fired Horizontal Return Tubular Boiler.

In the United States the most commonly used boiler is the horizontal return tubular boiler set in brickwork. The fire is under the boiler, the products of combustion pass to the back end and then come forward through the tubes. Common sizes are from 24 in. to 90 in. in diameter, and in some of the latter the heating surface amounts to more than 4 000

sq. ft. Boilers of this size are rated at 400 h.p. and some are worked up to 1 200 or 1 300 h.p., and have been for eighteen years or more.

Boilers of this type have been built up to 120 in. in diameter, and in my opinion are practicable and safe even for 200-lb. pressure or more. The plates would be thick, but the heat-conducting power of thick plates is almost as good as that of plates of the thickness commonly used, and the water has unlimited capacity to absorb the heat.

Dirt on the fire side of plates prevents heat from entering them, the plates themselves present almost no resistance to the flow of heat, and dirt on the water side of the plates prevents the heat from leaving them, and is the sole cause of overheating. Such dirt has the same effect on thin plates as on thick, and sometimes causes bulges. Bulging, however, does not cause explosions, and it can be prevented from increasing by keeping the boilers clean. It is best to allow dirt to accumulate on the outside of the bottom plates, as it is a slight protection, and its loss as efficient heating surface is slight.

Referring still further to thick plates, in 1890 an important paper was read before the North East Coast Institution of Engineers and Shipbuilders in England, by W. Kilvington and Alexander Taylor, on the use of thick plates for the furnaces of marine boilers. It had been for many years considered that $\frac{3}{8}$ in. was the greatest advisable thickness for such furnaces. This after a few years was increased to $\frac{1}{2}$ in., and in 1890 few engineers objected to furnaces $\frac{5}{8}$ in. thick. In 1890 there had been furnaces at sea for three or four years $\frac{3}{4}$ in. thick and subjected to 160-lb. pressure without failure. About the same change of opinion on this subject has taken place in regard to the thickness of plates of horizontal return tubular boilers.

The writers of the paper referred to stated that they knew of no furnace that had collapsed from being too thick. Cases of collapse have always been due to oil and dirt which accumulated on the furnaces, and this is the only cause of the bagging of horizontal return tubular boilers. It is also the usual cause of the bagging and explosions of the tubes of water-tube boilers.

The authors investigated the relative heat resistances of $\frac{3}{4}$ in. and $\frac{5}{8}$ in. plates and found that of the former only 1 per cent. greater than the latter. They show that this was long ago known by Rankine, who wrote: "The external thermal resistance of the metal plates of boiler flues and tubes, and other apparatus used for heating and cooling fluids, is so much greater than the internal thermal resistance, that the latter is inappreciable in comparison; and consequently the nature and thickness of those plates has no appreciable effect on the rate of conduction through them." Rankine also states that the results of evaporative tests of boilers justify the disregard of the effect of thickness on the rate of transfer of heat.

Kilvington and Taylor concluded that they would not hesitate to make furnace plates 1 in. thick, and that the same amount of scale would cause a thin plate to collapse as soon as a thick plate.

In 1867 Chief Engineer Isherwood, U.S.N., made some experiments on the transmission of heat through plates varying from $\frac{1}{8}$ in. to $\frac{3}{8}$ in. in thickness, a variation of 300 per cent., one side being exposed to steam and the other side to water, and the difference in the rate of heat transfer was not measurable.

All of the above reasoning applies to horizontal return tubular boilers, and the only inference to be drawn from it is that safety and efficiency are not affected by the thickness of the plates. Since 1880 thicknesses have increased from $\frac{3}{8}$ in. to $\frac{3}{4}$ in., and the writer has put in 90-in. boilers with plates having a thickness of $1/32$ in. more than $\frac{3}{4}$ in., and several 84-in. boilers with $\frac{3}{4}$-in. plates, which act in no respect different from boilers with thin plates. Some of these boilers have been in use nearly twenty years. All of these considerations show that there is no reason for anxiety in the presence of a well-designed boiler of the type under consideration if it has been built of good material.

The plates at the circular joints should be planed so that the double thickness at this point will not be excessive. This does not reduce the strength of the boiler, as the stress in a circular section of cylindrical boiler is very small and the two thicknesses at this point are greater than the thickness of the unreduced plate, so that longitudinal rupture at this point cannot occur.

Nor need there be any fear that the plate above the fire suffers in quality, for many boilers have been subjected to severe use for many years without apparent effect on the plates above the fires, and in one case, from a condemned boiler of the H. R. T. type, which had been in use many years, test pieces were cut from the plate which was above the fire, and the tests gave the same results as when the plates were new.

Riveted Joints.

It has been established, as I have before stated, that the cause of explosions of horizontal return tubular boilers has been the existence of lap longitudinal joints. This was due to the departure of the shell at the joint from the circular form and the consequent many bendings of the plate in the effort to become circular when pressure was applied. With the application and removal of pressure and the consequent bending back and forth of the plates, they finally cracked. If they are maltreated in bending, as plates in the past have been, they will crack all the sooner.

This was overcome by butting the plates and placing a covering plate on each side. Since this was done only one explosion of a horizontal return tubular boiler with such joints has occurred, I believe, and that was not in the joint. It was at a badly corroded place which was thereby weakened.

The prevailing butt joint used in this country for shells and drums of boilers is defective and likely some time to cause explosions. The

reason for this is that the inside butt strap is wider than the outside, and the joint is a combination of the lap and butt, and is, therefore, defective. It is defective because it is a non-central resisting device and still bends the plate and may therefore cause cracking. It is not, for this reason, the best joint, and, considering the prime importance of safety, should be abandoned. The covering plates, or butt straps, should be of equal widths, with all rivets in double shear, and until they are so made, as they are in most marine boilers, some danger will exist. Several of these one-sided joints have cracked, but fortunately leakage showed the danger before an explosion occurred.

The circumferential joints of horizontal return tubular boilers are troublesome, and there is no need of their existence since there are rolls of sufficient length to roll up plates long enough for boilers having tubes 20 ft. in length. The Massachusetts rule limiting the length of longitudinal joints should be repealed, and permission should be given to use plates of any length to persons desiring to avoid circular joints.

Making the Most of Horizontal Return Tubular Boilers.

With the exception of several designs made by the writer, boilers of this type are not provided with as many tubes as possible and desirable. The boiler users' interests are thereby not sufficiently considered and unnecessary room is taken up by the boiler plant. The boiler makers seem to have some fear of providing the boilers with as many tubes as they can stand without disadvantage in any respect. Whether they think they will prime or in some way misbehave I do not know, but if perforated steam pipes (or dry pipes, as they are often called) are used and the steam nozzles are placed about midway between the ends, the boilers cannot be made to prime no matter how hard they are worked. I favor placing the tubes nearer together and higher in the shell than usual. I have designed many such boilers with no regrets. The effect of this in 90-in. boilers with 3-in. tubes 20 ft. long is to increase the heating surface and horse power 33 per cent., which is something that should not be ignored. The makers of this type of boiler are not sufficiently aggressive.

Method of Supporting Horizontal Return Tubular Boilers.

It is common to support this type of boiler by means of four or more brackets resting upon brickwork, or by suspending it at four points from two overhead steel beams resting upon columns. When this is done it is impossible to adjust the loads so that they will be equal at each point, and in fact three of them, sooner or later, will support the whole load, especially if the foundation settles. This shows the folly and danger of using anything but the three-point suspension, provision for which should be made in the first place. When the boiler itself determines the three points, one

support will be overstrained. A three-legged stool rests firmly upon any irregular surface, and is just as stable if one or more points settle.

The three-point suspension was originated by the late Orosco C. Woolson, of New York, and for this he has not been sufficiently honored. When the three-point suspension has been carried out, connection has been made to four points on the shell, but the two rear points have been connected to an equalizing beam above, which has been hinged to the beam resting upon the supporting columns. A simpler, better and cheaper method is to have the rear end supported by a bracket riveted to the rear head of the boiler, as thereby harmful stresses will be removed from the shell and none added to the head. From this bracket a rod would pass to the supporting beam above.

I recommend that all boiler users insist upon the three-point suspension, as it is the only scientific and safe method.

Size of Tubes in Horizontal Return Tubular Boilers.

It is a great mistake to make the tubes of horizontal return tubular boilers over 3 in. in diameter. By using larger tubes, less surface is provided in a given boiler, the gases are not split up in small streams and do not so well impart their heat to the boiler, and the gases have a better opportunity to utilize a part of the tubes. All of these things reduce efficiency. If the coal has a good deal of volatile matter the case is not altered, and the use of 4-in. tubes, which are employed west of the Hudson River, is a mistake. If small tubes are likely to become stopped by soot with western coal it is advantageous because it compels the tubes to be kept clean.

Height of Boilers above Floor.

There is a mistaken policy at present, of mysterious origin, of, in general, placing boilers very high. This is done for the purpose of obtaining room for combustion on the assumption that great room is necessary. It is overlooked that horizontal space, when such is available for gas travel, is as good as vertical, and the only boilers that lack in the former are water-tube boilers with transverse baffles. The only way to obtain combustion space in these boilers is to place them high, and I am inclined to think that they are responsible for the mania. I have earlier in this paper made some comments upon this.

With other types of boiler, such as the horizontal return tubular and horizontal water-tube boilers, the space is abundant for the best results, even with low settings. This is apparent when it is considered that the best combustion can be obtained in the furnaces of Scotch marine boilers, in which there is almost no vertical space and no great horizontal space, with the added assumed disadvantage that the fire and evolved gases are surrounded at close quarters with steel plates in contact with water.

If air can be admitted where it will penetrate the combustible gas the combustion will occur instantly. The narrower this space the more perfectly the necessary mixing will occur. For this reason it is apparent that the greater the elevation of boilers with horizontal gas travels the more uncertain the gas and air mixture becomes, and the more the boilers are elevated the less efficient the boilers are. It should not be forgotten that horizontal return tubular boilers when set low have low combustion space only at the center.

The elevation of the boilers with transverse baffles only to a slight extent improves the mixture, as currents are almost vertical and parallel and have but little opportunity to mix and burn. Elevating such boilers is only groping in the dark, and with most other types elevation is harmful. When, in connection with this, the extra cost of the brickwork and the greater opportunity for cracks, which admit air that does not support combustion and cools off the boiler, are considered, the harm of high settings is evident.

The best place to admit air to hand-fired boilers, especially with horizontal gas travel, is at the bridge wall, for the air then has the best opportunity to penetrate the combustible gases. There are devices on the market for doing this.

In the case of mechanical stokers, the above remarks concerning space apply, but with pulverized coal more space is required because the fuel moves; but here again horizontal space is as effective as vertical.

Height of Bridge Walls.

The height of bridge walls appears to be a matter of great uncertainty, as they are sometimes made low and sometimes high.

The main purpose of a bridge wall is to limit the fuel bed and to prevent the coal from being thrown over it. Many bridge walls in marine boilers are only 9 in. high, because the furnaces are small. They answer the purpose, and it is safe to say that no bridge wall need be over 12 in. high, or 15 in. at most. The bridge wall, so far as its height is concerned, does not assist in burning carbon to CO_2, which is the great object in view, and other considerations must therefore determine its height. A high bridge wall might project a great quantity of hot gas on a part of the boiler within which dirt has lodged, and thus cause overheating and injury. There is no doubt that if the combustion is complete the heat will be absorbed without being directed against a small part of the shell. If boilers are set very high, a high bridge wall may cause air to reach combustible gases that it would otherwise be unable to encounter, but I can see no other advantage.

The Vertical Fire-tube Boiler.

This type of boiler is used extensively in the New England States, and is an excellent form. It is not only an efficient evaporator but it superheats the steam from 15° to 40° F., depending upon the length of tubes exposed to the steam, and being an internally fired boiler is free from air leaks and is therefore not subject to this source of inefficiency. The steam can still further be superheated by means of the locomotive type of superheater.

The boiler suffers from having parallel vertical gas currents, and therefore needs careful firing. With such firing it gives excellent results.

A vertical tube absorbs heat throughout its circumference and is perhaps a better heat absorber than a horizontal tube. The tubes sometimes leak at the lower ends, but this can be prevented by welding them in, as is commonly done on locomotives.

Many persons think that there is an inherent lack of economy in such boilers, the argument being that as the tubes are vertical the gases rapidly pass out and do not leave their heat behind. This is a superficial view and has no scientific foundation. The truth of the matter is that the damper is opened sufficiently to burn the amount of coal necessary to produce the desired amount of steam in a unit of time, and as a result a certain number of cubic feet of gas pass through the tubes in that time. This fixes their velocity and they can move no faster than if they passed through horizontal tubes.

An important thing in connection with this type of boiler is usually neglected, viz., air-tight smoke-box construction. The smoke box should be the extended shell, or a shell tightly riveted or bolted to the boiler. If this is attended to, the escaping gases will be hotter than in boilers set in brickwork. This is true of other internally fired boilers, such as the locomotive and Scotch. This is important where economizers are used, to say nothing of conservation of chimney draft.

Another advantage of this boiler is that less draft is required than with other types, which is probably due to its acting at right angles to the fuel bed, the air thus encountering less resistance.

I have made two designs of vertical boilers with corrugated fire boxes such as are used for the furnaces of Scotch marine boilers. By this means the use of staybolts is avoided. This I consider the best way to design vertical boilers. The inside minimum diameter of such furnaces is limited to 6 ft., but the diameter of the grate can be 3 in. larger.

Locomotive Type Boilers.

This type of boiler is one of the best, and always gives economical results. It can be made from very small to very large sizes, and to carry any pressure. The Pennsylvania Railroad has a locomotive with a boiler having a maximum diameter of 110 in., a total length of 53 ft. $9\frac{1}{2}$ in., a

maximum thickness of plate of $1\frac{5}{16}$ in., a water-heating surface of 6 656 sq. ft., superheating surface of 3 136 sq. ft., and carries a pressure of 225 lb. They also have boilers carrying 250 lb. The only limit in size to this type is the ability to transport it.

The locomotive type of boiler presents an opportunity to use a brick arch which is used in most locomotives. This lengthens the path of the gases, which otherwise would be very short, and presents an opportunity for the air which passes through the fire door to mingle with the gases and burn any CO which may be escaping, to CO_2. I think that it is hardly an exaggeration to say that the locomotive type of boiler provided with a brick arch is the most economical of all boilers.

The objections to the boiler are its cost and the depth of the boiler house required to provide room to clean or remove the tubes, as it is best to do this under cover.

Forcing Capacities of Boilers.

Boilers do not differ much in this respect. Any boiler can be forced to an unlimited extent if the necessary fuel can be burnt. Underfeed stokers usually have fan capacity enough to force boilers beyond usual rates, but all kinds of boilers, whether fire or water-tube, are capable of this forcing. Rapid steaming of boilers does not depend upon the amount of water which they contain, after the water is once heated to the temperature of the steam, as further heat can only make steam. It depends upon the quantity of fuel burned in a unit of time, and the perfection with which the hot gases circulate among the heating surfaces. Fire-tube boilers excel in the latter respect. Of all boilers, the locomotive type of boiler on locomotive is forced most. The tubes of water-tube boilers are no better heat absorbers than those of fire-tube boilers, and probably not as good if the path of the gases is transverse to the tubes.

High Boiler Pressures.

Both fire- and water-tube boilers can be made for very high pressures, the former, say, up to 350 lb., and the latter somewhat beyond if the risk of tube explosions is ignored.

Reduction of Pressure from Age.

It is customary to reduce the pressure of fire-tube boilers after a time, on general principles. There is as much reason for reducing it on water-tube boilers, and if there are no apparent defects there is no reason for reducing it on either, except for the possibility of hidden defects. When a serious reduction of pressure is contemplated, or when a boiler is to be condemned, it would be best to remove a sufficient number of tubes, and

even to remove the butt straps, to enable a complete examination to be made. If no serious defects can be found, these parts should be replaced and the boiler continued in service and considered as good as new.

The Safety of Boilers.

Boilers, if designed with butt longitudinal joints having all rivets in double shear, and with no parts so made that they will bend when subjected to strain, are as safe as any structure if they are kept clean and free from corrosion. The causes of explosions of water tubes are being investigated, and there is evidence that a harder and stiffer steel than has heretofore been used is advantageous.

Rivet Heads.

It is customary for boiler makers to use conical rivet heads, known as "steeple heads." This is a relic of the past which seems to have escaped the notice of most boiler makers. Nobody would think of making any other part of a mechanical structure like this, that is to say, one with slanting sides coming down to a knife edge. It would be bad construction, and it is no better when it is a part of a boiler. It is bad because the holding power of the rivet diminishes to nothing toward the edge, it has no edge to calk when this is necessary, and needs calking oftener than other forms.

The so-called "button head" is free from the above defects. It is used exclusively by the American Locomotive Company, the Baldwin Locomotive Works, the Pennsylvania Railroad, and all leading makers of marine boilers.

The button head should be required by all specifications.

Water Glasses and Gage Cocks.

In the United States it is customary to equip each boiler with one set of gage cocks and one water glass for showing the height of the water. I prefer to have two water glasses and no gage cocks, as the latter are seldom used and the former provide two means of observation of the height of the water.

Feed-water Regulators.

It is becoming a growing custom in this country to use feed-water regulators on boilers. There are several makes and they simultaneously control the admission of water and the speed of the pumps. They have proved to be reliable and maintain a steadier water level than is otherwise possible, especially in a large plant.

Superheaters.

Superheated steam is commonly used in many steam plants. It economizes steam in an engine by reducing cylinder condensation. Although it requires heat to superheat the steam, which might be used for evaporating water in the boiler, there is an important net gain by the use of such steam. The saving in steam used by an engine amounts to about one per cent. for every 10° F. of superheat. Superheaters can be applied to most boilers.

Very high superheat is troublesome on account of distortion of valves and some other parts, but 150° F. is safe, with ordinary pressures.

Soot Blowers.

An objection to water-tube boilers has been that the tubes could not well be effectively cleared of soot. Within a few years, however, blowers have been devised, and are now commonly used, by which the soot can be blown off more effectively than heretofore. As before stated, the use of horizontal baffles and hollow staybolts in boilers with headers promote this. All boilers, whether water-tube or fire-tube, should be equipped with soot blowers, and required by the specifications. Their use is advisable as they produce a real economy in coal, are easily and quickly used, and are more likely to be used in consequence.

In one of the Emergency Fleet boilers, which was provided with electrical temperature-recording apparatus, the tubes were blown every two hours during some tests, and the temperature of the escaping gases fell 35° F. each time, when hand-fired. With the same boiler, when stokers or oil were used, there was no drop in the temperature at the two-hour intervals, and the blowing was afterwards done less frequently.

Temperature of Escaping Gases.

It is difficult to ascertain the temperature of the escaping gases from a boiler, because it differs in different parts of an uptake, and to find the position of average temperature is a matter of guesswork. Moreover, samples of gases differ in composition from different parts of an uptake.

Mechanical Stokers.

In many situations the efficiency of a hand-fired boiler when skillfully fired equals that with a mechanical stoker, and when allowance is made for the steam used by the stoker will surpass it. There is no opportunity in most pumping stations for mechanical stokers. Their fields lies where they can reduce the cost of labor.

The prevailing type of mechanical stoker is the underfeed, which is made in several ways. They require to be driven by power, and considerable power is required to blow the air.

Pulverized Coal.

Pulverized coal has been known for several years as a desirable form of fuel, but the difficulty, now overcome, has been to pulverize the coal to sufficient fineness. It is desirable that this should be such that at least 85 per cent. of it shall pass through a mesh of 200 per inch. Some pulverizers even surpass this with most kinds of bituminous coal.

When this kind of fuel is used it is blown into an empty furnace with the proper quantity of air, and flashes into flame when the furnace is incandescent. As it is a moving fuel it requires considerable volume for combustion. Every little particle of coal is accompanied with air in but slight excess, and as a consequence more perfect combustion, which is smokeless, results than by any other means. Any kind of coal can be used, and coal that cannot be used either by hand or stoker firing can be used as well as the best.

As no part of the mechanism is exposed to heat, it is evident that the maintenance cost is very low compared with that of stokers. Moreover, the complication of a stoker is done away with.

There are two general systems of producing and burning pulverized coal, one in which the coal is first dried, then pulverized, then blown into a storage bin, then conveyed to the vicinity of each boiler, where it is taken by a so-called burner, and blown into the furnace, and another in which the coal is neither dried nor pulverized in advance, and which has no burner. The pulverizer in the latter case delivers the coal into the furnace and is operated only when the boiler is in service.

By means of pulverized coal the boiler performance is continuous, and the fire does not require cleaning.

Hand Stokers.

There are now on the market so-called hand stokers which only require the coal to be placed on the end just inside of the fire doors. By means of a lever the bars of the stoker, which are transverse to the depth of the furnace, are rotated and advance the coal toward the bridge wall, the last bar dumping the ash and clinker into the ash pit. No cleaning of the fire is necessary, and the steaming of the boiler is nearly continuous. As the coal is placed only on the front of the grate the smoke is diminished in consequence of the gases which are first liberated passing over incandescent coal. This maintains their temperature, and if sufficient air is admitted the smoke is reduced. It is obvious, however, that it is still possible with it to admit too little or too much air, and easy to dump too much combustible matter at the end.

Oil Fuel.

Oil is an ideal fuel for boilers because it is easily handled, requires minimum attendance, and produces no ashes. It should not, however, usually be employed for land boilers, because its best field is for ocean service, is so necessary for lubricants and other purposes, and because its occurrence in nature is so uncertain, if not insufficient.

It can be burnt without smoke, but if I am to judge from appearances the smokiest chimneys in Boston are those from oil-burning boilers.

Mechanical atomization is preferable to steam, because in the latter case it is very easy to waste steam, and there are no easy means of determining when the waste occurs.

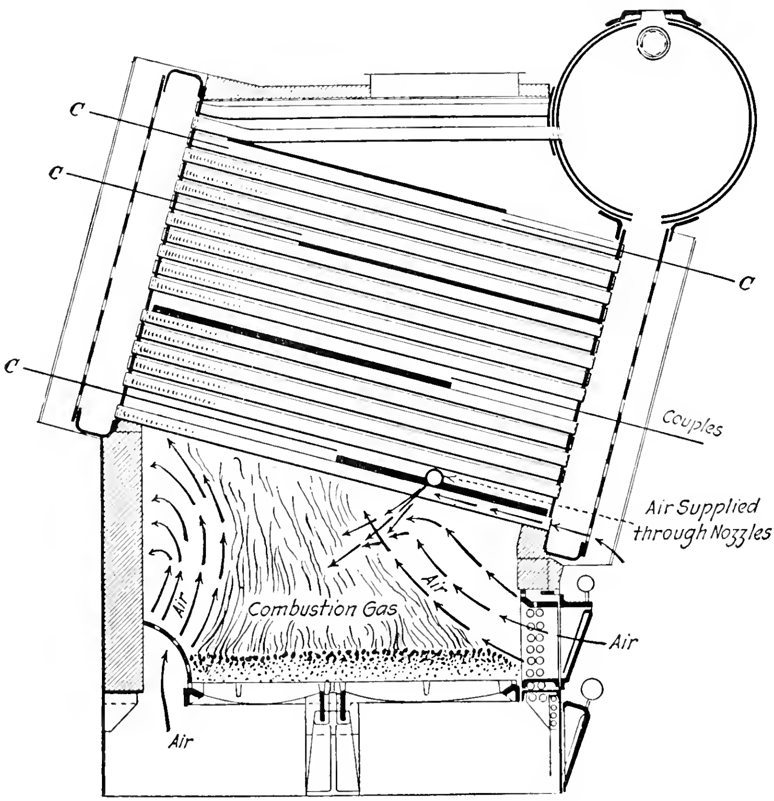


Fig. 1.

Grate Bars.

Grate bars are made both fixed and shaking. The latter are not necessary for the best results and can easily be a means of wasting coal by too much agitation. The labor of cleaning fires is reduced by the use of shaking bars, and in the effort to avoid this labor they may be shaken so

much as to be wasteful. In most cases fixed grates are advisable. In cases where it is the policy to force boilers, shaking bars are best.

Bars for bituminous coal should in general have 50 per cent. of air space, and the iron and air spaces should each be $\frac{1}{2}$ in. wide. The parts in contact with the coal should be rounded on top and so formed that the air can have access as much as possible to the whole under side of the coal,

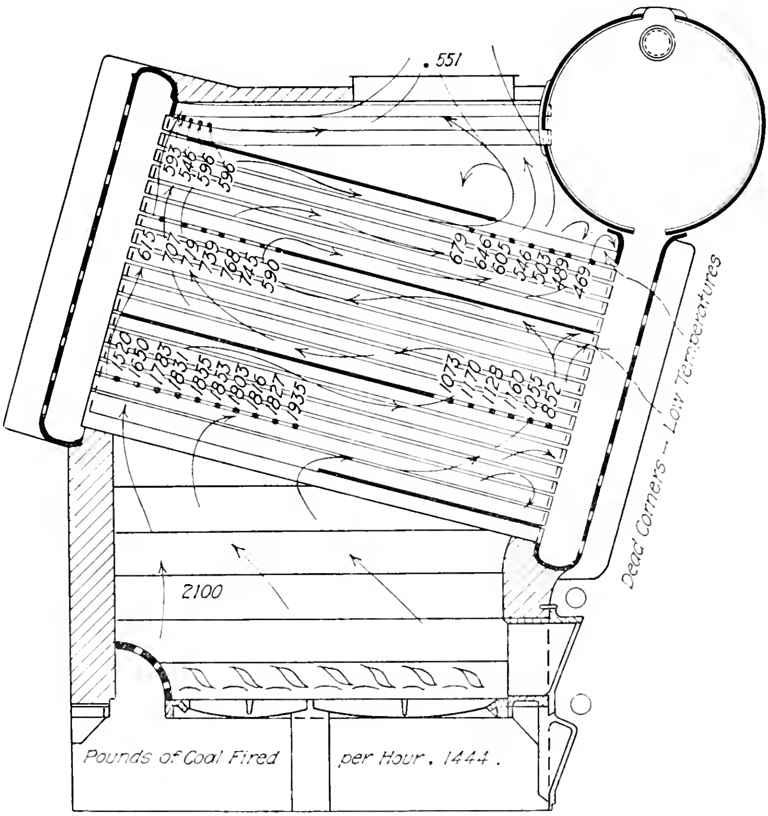


FIG. 2.

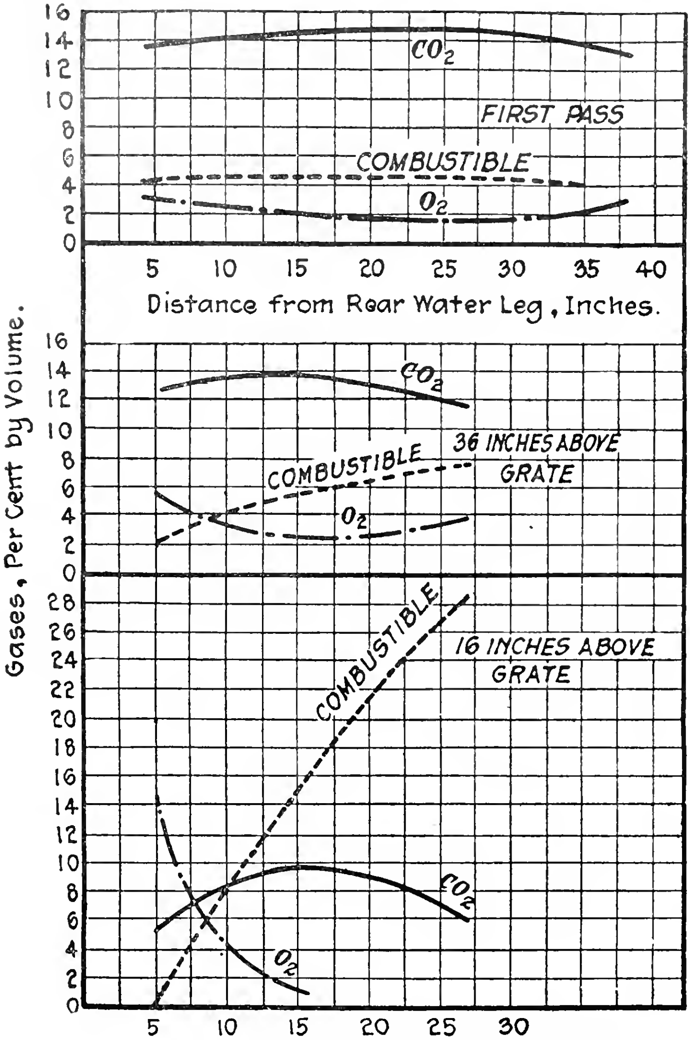
except where the coal actually touches the grates. There are such bars on the market, and the air spaces amount to virtually almost 100 per cent. It is not possible to have too much air space, and even with the maximum, the formation of CO cannot be prevented except by air admission elsewhere.

Shaking grate bars are of little use with coal that forms a continuous tenacious slab of clinker over the grates, as they only scrape the bottom of such clinker, and the slice bar is still an important tool.

FEEDING BOILERS.

Boilers are fed by pumps or injectors. If there is exhaust steam available for heating the feed water, pumps and a heater should be used. If there is no exhaust available, injectors should be used. The reason for

this is that any kind of piston engine, such as a steam pump, condenses a large part of the steam in its cylinder, and therefore only a part of the steam used is available for heating, while with the injector all of the heat in the



Analysis of Furnace Gases.
Tests No. 6 and No. 7.
Jan. 19 to 20.
Air Supplied by Draft through Bridge Wall.

FIG. 3.

steam is returned to the boiler, except a very little which is used in starting the injector and in pipe condensation. Exhaust steam should not be made for the sake of using it.

Notes Concerning Some of the Results of the Tests of the Emergency Fleet Boiler for Wood Ships.

Two of these boilers, one 3-pass and one 4-pass, were subjected to exhaustive tests on land, and the following notes refer to the 4-pass boiler.

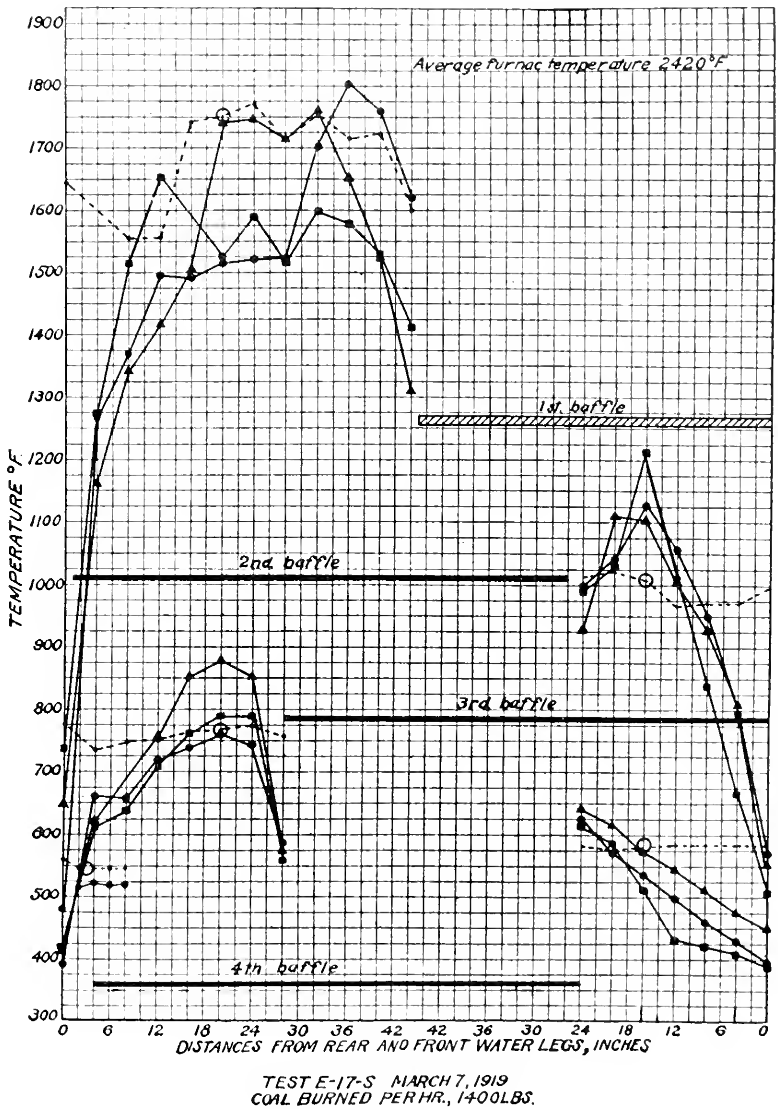


Fig. 4.

Fig. 1 shows the boiler in outline with air being introduced at the back of the grate, through and around the fire doors, and through perforations in a pipe above the lowest row of tubes. The latter arrangement was

not used during the tests to which the notes refer, but the other arrangements were.

Fig. 2 shows the paths of the gases among and around the baffles, as plotted from temperatures, taken by means of thermocouples, and drafts. The thermocouples and draft gage pipes were inserted through hollow staybolts. Some of the corners were dead and much of the heating surface was ineffective, as it is in all boilers. The figures show the gas temperatures in degrees F.

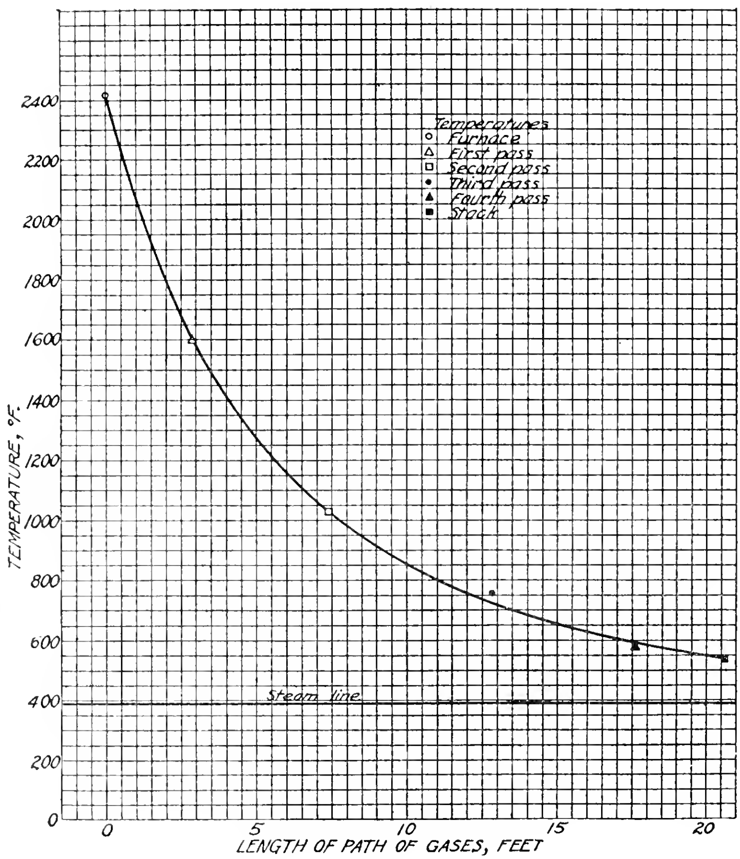


Fig. 5.

Fig. 3 shows the gases of combustion at three different heights above the grate, and at several distances from the rear furnace wall. They show how rapidly combustible gases are consumed and CO_2 formed when air is admitted at the proper place. From this it is evident that the large furnaces about which we hear so much are unnecessary, at least with good semi-bituminous coal such as was here used. The rate of combustion was about 20 lb. per sq. ft. of grate per hour.

Fig. 4 shows furnace and gas temperatures throughout the tubes and baffles as given by thermocouples. The lowest baffle is at the top of the diagram in order to be properly related to the high temperatures in its vicinity. The dotted line gives temperatures of a fixed thermocouple in the positions indicated by circles. These were read simultaneously with the movable thermocouples, in order to have means of determining as well as possible the effect due to the heat developed as well as to position. These diagrams show that the greatest temperatures are near the ends of the baffles, and from this it is evident that most of the gases take the shortest paths and pass close to these ends. From this it may be inferred that horizontal baffles may be longer than they are customarily made.

Fig. 5 shows the manner in which the gas temperatures fall in their path throughout the boiler from the firebox to the uptake.

Discussion.

Mr. Richard A. Hale.* I would like to ask Mr. Dean if in this oil combustion, where you get such intense heat, there is an injurious effect on the boiler plates by burning? Does any part of the rivet sheet receive any intense heat? I was wondering whether it burned the plate or injured the boiler.

Mr. Dean. I do not think that there would be trouble from this source unless dirt is present on the water sides of the plates. Riveted joints are frequently subjected to the heat of combustion.

Mr. Henry J. Williams.† Has the fluxing of pulverized coal when blown into the furnace been overcome?

Mr. Dean. Yes, it has been overcome. There is a furnace which has a so-called water jacket and has tubes in the sides, and they are covered with box tiles. The temperature of the sides is reduced so that the slag usually drops down before it gets there. That is, it drops down as a powder. It is also overcome by introducing air into the sides of the furnace to reduce the temperature. In such furnaces without the water-jacket arrangement, which is quite expensive, if you keep the CO_2 to 14 per cent. and less and introduce air slightly at the sides, you will have no trouble. All you will get in the bottom of the furnace is a light powder, which looks like tooth powder, so that I think the trouble has passed now with pulverized coal. You can easily run a furnace so as to get 16 or 17 per cent CO_2, and then the temperature is so high that the ash melts, and can be caught in slag cars.

Mr. A. O. Doane.‡ Would it be advisable to put pulverized coal or oil fuel into a vertical boiler?

* Principal Assistant Engineer, Essex Co., Lawrence, Mass.
† Fuel Engineer, Boston.
‡ Division Engineer, Metropolitan Water Works, Boston.

MR. DEAN. You cannot use pulverized coal in a vertical boiler unless you have an enlarged furnace, because you have not the length of travel sufficient to give it a proper length of time to be consumed. Oil, however, does not require so much volume, and is used in vertical boilers considerably.

MR. EDWARD D. ELDREDGE.* What is the cause of the situation that we sometimes see when the CO escapes from the top of the uptake and is not burned until it reaches the atmosphere?

MR. DEAN. CO is always formed in a furnace to some extent, and if the firing is very poor you cannot get sufficient oxygen into the gases to complete combustion. If one part of oxygen joins with the carbon you have a partially burned gas, which is still capable of being burned if an additional part of oxygen comes in contact with it. Now, that gas can go up through the boiler, and sometimes its temperature is high enough to burn if oxygen gets to it, and it often does, through leaks in the uptake.

I remember seeing on Moosehead Lake a steamer, some years ago, that had a stream of flame from the stack, caused in this way. I also once saw a locomotive on the Erie Railroad with flame issuing from the stack. That used to be the regular thing, quite a good many years ago, on steamers going from Liverpool and Holyhead over to Ireland. It was a mystery for a long time, but they finally found out that it was due to insufficient air.

On the Pacific Coast, when the first wood ship was started with the Emergency Fleet boilers, they had that trouble. They could not make any speed on the trial trip, but they secured an expert in San Francisco, who understood the situation at once. He told them to leave the fire doors wide open, and when they did that the boiler immediately improved in performance. Of course that was overdoing the matter, but it stopped the trouble. Later he made an arrangement for admitting air above the fire, and the boilers then worked perfectly well.

* Superintendent, Water Works, Onset, Mass.

PROCEEDINGS.

Annual Meeting.

Boston City Club,
Thursday, January 12, 1922.

The President, Mr. Charles W. Sherman, in the chair.

The President. In accordance with the requirements of the Constitution, the time for filing ballots for officers for the ensuing year ends now. If anyone has a ballot that has not yet been cast and cares to cast it now, he may pass it in to the Secretary; if not, I shall declare the ballot closed. Are there any others? (No response.) The ballot is closed.

Since our last meeting the Association has suffered severely by death. We have lost a man who was practically always present at the meetings, whom all of us knew and liked, and who has done an immense amount of work for the Association, although he did not hold personally a membership, being a representative of an associate member. I refer, as most of you gentlemen probably realize, to our late friend, Thomas E. Dwyer, whose death occurred a short time ago.

We have also lost one of our past presidents and an honorary member of the Association, — George A. Stacy of Marlborough.

I will ask the members to stand in silence for a moment in memory of these friends.

(Everybody stands.)

The following were duly elected members of the Association:

Active: Allen F. McAlary, Superintendent Camden & Rockland Water Co., Rockland, Maine; Arthur Daniels Weston, Principal Assistant Engineer, Engineering Division, Massachusetts Department of Health.

Associate: Metalium Sales Co., 50 Broadway, Providence, R. I.

The President. The next business before us is action upon the proposed amendment to the Constitution, which was reported to the last meeting and recommended by the Executive Committee, as follows:

"Amend Section 2, Article 8, by striking out the word 'Wednesday' and inserting the word 'Tuesday' in place thereof, so as to read:

"Section 2, Article 8. There shall be two general business meetings of the Association each year: first, the annual meeting, which shall be held in Boston on the second Tuesday in January, and at which the annual reports for the year ending December 31 shall be presented and

the ballot for officers canvassed; and second, a business meeting during the annual convention.

"Amend Section 3, Article 8, by striking out the word 'Wednesday' and inserting the word 'Tuesday' in place thereof, so as to read:

"Section 3, Article 8. In addition to the above, business meetings shall be held on the second Tuesday of the months of November, December, February and March, and, at the discretion of the Executive Committee in June."

This proposed change in our meeting day from Wednesday to Tuesday is in order to make it possible for us to continue to come here to the City Club if it shall prove acceptable to the membership as a whole, as I judge from appearances it has so proved today. We cannot come here on the second Wednesday, our old date, under any circumstances, as the Rotary Club has the Club facilities engaged for an indefinite time in the future on the second Wednesday of each month, consequently it requires some change, and it seemed to the Executive Committee in suggesting this amendment that Tuesday would be equally acceptable to the Association and it would make it possible for us to come here, or, of course, if that is not satisfactory, to go anywhere else just as much as on Wednesday. Is there any discussion on the proposed amendment?

Mr. George A. King. I do not know whether this need affect the present amendment, but it has been my opinion, and from my experience as President I believe that the annual meeting should be held at the convention, and that the year should begin at the close of the convention in September. As it is today, the President cannot form any policy for the organization, coming in as he does in the middle of the term of our activities, but a man coming into office say the first of October would have a chance to formulate a policy for the winter and have an opportunity to carry it out. As it is today, we have our election in January and probably the Executive Committee will not meet until February. Then there is only one meeting more before the close of our winter meetings, then there is a long vacation and we meet again in September, and there are only the meetings in November and December after the convention, and the President lets things slide as a general rule. I think it would be much better for the Association and much better for the President who has something in his mind he would like to carry through, to have the election say the first day of the convention and have the new officers take office in October. I doubt if we could pass on that at this meeting with this short notice, but that is something I have advocated, and when the Committee on Revision of Constitution a year or two ago asked for suggestions that was one of those which I made.

The President. I think the point is very well taken, Mr. King. I also think that your point of order that we cannot act on this today is also correct. For your information and that of the membership, I want to say that the Committee on Revision of Constitution to which you refer

is still in existence and has practically completed its labors. I am informed that it has a proposed revised form of constitution now drafted which will be submitted to the Association at a very early meeting, and if I understand correctly it would mean a pretty radical revision of the whole constitution, and I may perhaps be permitted to say that I think it is about time.

Is there any other discussion? (No response.)

(The question was put and the amendment to the Constitution unanimously adopted.)

The following reports of the officers of the Association were received:

Report of the Secretary.

January 3, 1922.

Mr. President and Gentlemen of the New England Water Works Association,— The Secretary submits herewith the following report of the changes in membership during the past year, and the general condition of the Association.

The present membership is 828, constituted as follows: 10 Honorary, 742 Active, and 76 Associate Members, there being a net loss for the year of 44. The detailed changes are as follows:

MEMBERSHIP.

January 1, 1921.	Honorary Members	14			
	Died	4			10
January 1, 1921.	Total Members			788	
	Withdrawals:				
	Resigned		39		
	Dropped		31		
	Died		10	80	
				708	
	Initiations:				
	January		4		
	February		2		
	March		4		
	June		4		
	September		12		
	November		2		
				28	
	Reinstated:				
	Members resigned in 1917		1		
	Members dropped in 1919		3		
	Members resigned in 1920		1		
	Members dropped in 1920		1	6	742
January 1, 1921.	Total Associates			70	
	Withdrawals:				
	Resigned		1	1	
				69	

Initiations:			
February	1		
September	4	5	
Reinstated:			
Associate resigned in 1918	1		
Elected in 1920, qualified in 1921	1	2	76

January 1, 1922.	Total membership	828
January 1, 1921.	Total membership	872
	Net loss	44

Members Elected in 1921.

January. Bernard S. Coleman, Roger W. Esty, Charles A. Hatch, Alexander H O'Brien. (4)
February. Harry W. Dotten, Spencer W. Stewart. (2)
March. Walter F. Abbott, Clarence E. Carter, Harry C. Kerr, August G. Nolte. (4)
June. D. H. Hall, Albert E. Lavery, F. E. Hammond, E. R. Conant. (4)
September. Harry E. Collins, Donald M. Hatch, Benjamin H. Keeler, Jr., William A. Megraw, S. John Scacciaferro, Henry L. Shuldner, John O. Taber, Jr., R. H. Blanchard, Ivan Escott, R. F. Johnson, Frank N. Strickland, George C. Ham. (12)
November. John C. Adams; Fred W. Young. (2)
December. Alfred Bétant. (1) *Did not qualify up to December 31, 1921.*

Reinstated:

Resigned in 1917 (L. E. Thayer)	1
Dropped in 1919 (F. H. Gunther, John J. Philbin, G. Z. Smith)	3
Resigned in 1920 (F. W. Dean)	1
Dropped in 1920 (Allston F. Hart)	1
	6

Associates.

February. Ambursen Construction Company, Inc. (1)
September. Continental Pipe Mfg. Company, Linus G. Read, Payne-Dean Ltd. (3)

Reinstated:

Elected 1920, qualified 1921, (Lawrence Machine Company)	1
Resigned in 1918 (Am. Manganese Bronze Company)	1
	2

Resigned:
Public Works. (1)

Honorary Members.

Died: Hiram F. Mills, William T. Sedgwick, Fred W. Shepperd, George A. Stacy. (4)

Members.

Died: Samuel M. Gray, Charles E. Haberstroh, E. L. Hatch, S. S. Hatch, R. A. McKim, William M. Stone, Richard L. Tarr, Samuel E. Tinkham, Albert H. Wehr, Charles W. Young. (10)

Receipts for 1921.

Initiation fees			$178.00
Annual dues:			
Members	$4 444.02		
Associates	1 440.00	$5 884.02	
Fractional dues:			
Members	$45.00		
Associates	25.00	70.00	
Past dues		21.08	
Total dues			$5 975.10
Advertising			3 120.77
Subscriptions			390.00
JOURNALS sold			140.73
Sundries			191.94
Total receipts			$9 996.54

There is due the Association:	
Advertisements	$551.00
Reprints	24.00
JOURNALS	7.50
Total	$582.50

Respectfully submitted,

FRANK J. GIFFORD, *Secretary.*

REPORT OF TREASURER.

CLASSIFICATION OF RECEIPTS AND EXPENDITURES.

Receipts.

Dividends and interest		$190.04
Initiation fees	$178.00	
Dues	5 975.10	
Total received from members		$6 153.10
JOURNAL:		
Advertisements	$3 120.77	
Subscriptions	390.00	
JOURNALS sold	140.73	
Sale of reprints	101.69	
Cuts sold	10.83	
Total received from JOURNAL		$3 764.02

Miscellaneous:		
Sale of "Pipe Specifications"	$40.25	
Membership lists	5.00	
Buttons	2.25	
Certificates of membership	7.50	
Meter rate sheets	4.25	
Exchange	1.00	
American Water Works Association	10.23	
Total miscellaneous receipts		$70.48
Total receipts		$10 177.64

Expenditures.

JOURNAL:		
Advertising agent's commission	$226.10	
Plates	4.33	
Printing	4 493.08	
Editor's salary	300.00	
Editor's expense	7.56	
Reporting	326.30	
Reprints	453.66	
Envelopes and postage	74.78	
		$5 885.81
Office:		
Secretary's salary	$200.00	
Assistant Secretary's salary	1 080.00	
Assistant Secretary's expense	54.94	
Rent	750.00	
Printing, stationery, and postage	354.72	
Membership lists	304.30	
Telephone	14.21	
		$2 758.17
Meetings and Committees:		
Stereopticon	$50.10	
Dinners for guests	24.70	
Music	1.50	
Printing, stationery, and postage	166.62	
Badges	62.50	
Miscellaneous	52.23	
		$357.65
Treasurer's salary and bond		67.50
Certificates of membership		2.50
Miscellaneous		86.21
		$9 157.84

LEWIS M. BANCROFT, *Treasurer*.

In account with the New England Water Works Association.

RECEIPTS.			EXPENDITURES.		
1921.			Bills paid		$9 157 84
Jan. 1. Balance on hand		$1 435.17	BALANCE ON HAND		
Received of F. J. Gifford, Secretary		9 996.54	Coupons	$40.00	
Interest on bonds and deposits		181.10	First National Bank	658.85	
			Liberty Trust	523.50	
			Mechanics Savings	232.62	
			People's Savings	1 000.00	2 451.97
		$11 612.81			11 612.81

ASSETS AND LIABILITIES.

ASSETS.			LIABILITIES.	
Cash balance in banks		$2 454.97	Surplus	$4,852.47
Bonds Nos. 2642 and 2644 Lake Shore & Michigan Southern R. R. 4s, due 5-1-1931.		1 815.00		
Accounts receivable:				
JOURNAL	$7.50			
Reprints	24.00			
Advertising	551.00	582.50		
		$4 852.47		$4 852.47

READING, January 12, 1922.

LEWIS M. BANCROFT, *Treasurer*.

Report of Auditing Committee.

January 6, 1922.

We have examined the accounts of the Secretary and Treasurer of the New England Water Works Association, and find the books correctly kept and the various expenditures of the past year supported by duly approved vouchers. The Treasurer has also accounted to us for the investments and cash on hand, as submitted in the above report.

GEORGE H. FINNERAN,
FRANK A. MARSTON,
Finance Committee.

Report of the Editor.

January 12, 1922.

To the New England Water Works Association: I present the following report for the Journal of the Association for the year 1921.

As has been the custom, the figures presented are for Volume XXXV rather than the calendar year of 1921, and represent total charges and accounts paid and payable rather than actual cash received or disbursed.

The accompanying tabulated statements show in detail the amount of material in the Journal.

Size of Volume. — The volume contains 560 pages, an increase of 40 pages from that of 1920.

Reprints. — Twenty-five reprints of each paper have been furnished to the author without charge.

Circulation. — The present circulation of the Journal is:

Members, all grades	828
Subscribers	86
Exchange	15
Total	929

a decrease of 41 from the preceding year.

Journals have been sent to all advertisers.

Advertisements. — There has been an average of $31\frac{1}{2}$ pages of paid advertisements, with an income of $2 921.68, an increase of $162.33 over last year.

Pipe Specifications. — During the year the specifications for cast-iron pipe to the value of $15.25 have been sold. The net gain up to a year ago had been $322.10 so that total net gain from this source to date is $337.35 and 84 copies of specifications on hand, — $21.00 worth if sold at retail.

Post-Office Accounts. — The Association has a credit of $2.15 at the Boston Post Office, being the balance of money deposited for payments of postage.

Meter Rate Sheets to the value of $4.25 have been sold during 1921.

TABLE I.

STATEMENT OF MATERIAL IN VOLUME XXXV JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1921.

Date.	Pages of Papers.	Proceedings.	Total Text	Index	Advertisements.	Cover and Contents.	Insert Plates.	Total.	Total Cuts.
March	57	33	90	0	35	4	0	129	9
June	60	54	114	0	37	4	0	155	5
September	91	1	92	0	35	4	0	131	6
December	86	17	103	3	35	4	0	145	9
Total	294	114	399	3	142	16	0	560	29

TABLE 2.

RECEIPTS AND EXPENDITURES ON ACCOUNT OF VOLUME XXXV, JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, 1921.

Receipts.		*Expenditures.*	
Advertisements	$2 921.68	Advertising agent's salary and commission	$254.30
Sale of JOURNALS	140.73	Plates	4.33
Sale of reprints	48.75	Printing	3 997.01
Subscriptions	390.00	Mailing postage	77.58
Sale of cuts	10.83	Editor's salary	300.00
		Editor's incidentals	7.82
		Reporting	326.30
		Reprinting	414.50
	$3 511.99		
Net cost of JOURNAL	1 869.85		
	$5 381.84		$5 381.84

Respectfully submitted,

HENRY A. SYMONDS, *Editor.*

TABLE 3.

COMPARISON BETWEEN VOLUMES XXV TO XXXV, INCLUSIVE (OMITTING VOLUME XXXI), NEW ENGLAND WATER WORKS ASSOCIATION.

	Vol. XXV. 1911.	Vol. XXVI. 1912.	Vol. XXVII. 1913.	Vol. XXVIII. 1914.	Vol. XXIX. 1915.	Vol. XXX. 1916.	Vol. XXXII. 1918.	Vol. XXXIII. 1919.	Vol. XXXIV. 1920.	Vol. XXXV. 1921.
Average edition (copies printed)	1 000	1 000	1 000	1 050	1 325	1 500	1 388	1 200	1 150	1 100
Average membership	752	740	745	803	904	1 002	954	902	885	861
Circulation at end of year	840	826	858	951	1 079	1 155	1 010	1 002	970	929
Pages of text	475	401	551	564	596	538	398	566	359	399
Pages of text per 1 000 members	632	542	746	702	659	538	417	627	406	462
Total pages, all kinds	654	567	733	719	776	707	557	726	520	560
Total pages per 1 000 members	870	766	984	895	859	707	584	805	588	648
GROSS COST:										
Total	$2 625.87	$2 476.55	$3 586.29	$3 345.87	$4 243.35	$3 386.63	$3 115.00	$4 967.99	$5 011.03	$5 381.81
Per page	4.02	4.37	4.89	4.65	5.47	1.79	5.59	6.84	9.64	9.61
Per member	3.50	3.35	4.81	4.17	4.68	3.38	3.26	5.51	5.66	6.23
Per member per 1 000 pages	4.09	5.90	6.46	5.80	6.02	4.79	5.85	7.59	10.88	11.12
Per member per 1 000 pages text	7.36	8.35	8.68	7.39	7.85	6.30	8.19	9.74	15.77	15.61
NET COST:										
Total	$352.82	$98.81	$1 322.90	$1 155.33	$2 091.09	$1 171.98	$694.50	$2 675.04	$1 722.14	$1 869.85
Per page	.51	.17	1.80	1.61	2.70	1.65	1.25	3.68	3.31	3.34
Per member	.17	.13	1.78	1.14	2.32	1.17	.73	2.97	1.95	2.16
Per member per 1 000 pages	.55	.23	2.42	2.00	2.98	1.65	1.31	4.09	3.75	3.87
Per member per 1 000 pages text	.98	.33	2.38	2.55	3.88	2.17	1.83	5.25	5.13	5.43

Mr. Symonds. Now, if I may be permitted, I would like to say a word informally. The advertising agent has an obligation to the Association to enlarge the business of the Advertising Department, to make the Journal advertising pay as large a return to the Association as possible. The advertising agent also has another obligation which is as great as the first, which is to see that the advertisers in the Journal are getting what they are paying for, that the value of the advertising is made good. Now, gentlemen, that is something which is to a very great extent up to you. When it is claimed, as it has been in times past in this Association, that the advertising was sort of a bonus paid the Association by the advertisers, if when you get your Journals you pay no attention to the advertising section, if when you get ready to purchase you forget that the advertisers in the Journal represent nearly every line of water works supplies, equipment and experts through a great number of leading firms, then you are making that statement absolutely good and we have no argument with it, for in that case, as a commercial proposition, the ads. are of no value.

Now, gentlemen, that is not a satisfactory condition for the advertisers nor for the Association, nor do I believe it is true at this time, but as the Journal should be, and has the advantages to make it, the best advertising medium for all water-works supplies of any of that kind that I know of, it rests with you, gentlemen, to say whether by your interest in this department of the work it shall be made so. If it can be made so and the advertising agent can go with a full belief, conscientiously, to prospective advertisers with this claim and something behind it, there is a prospect that we can greatly advance the income from this source, the value to the Association, and the general interest in the work of the Association. There are many sides to this particular question which I believe it is for your interest to consider.

Now, I may weary you at times by harping on this particular matter, but I believe it is my duty, and yours, to take a new interest in this department of the work and see if we can't build up a better and larger Journal, a better Association through larger income, and greater interest in the general work of the Association.

I thank you. (Applause.)

(On motion, duly seconded, it was voted that the report of the Editor be received and placed on file.)

The President. I hope that the informal remarks by Mr. Symonds will sink in and be borne in mind by everybody in a position to do so.

The next business is the report of the Tellers on the election.

Report of Tellers, January 12, 1922.

Whole number of ballots	300
Blanks	0
President.	
Frank A. Barbour	293
Scattering	1
Vice-President.	
Patrick Gear	295
George A. Carpenter	295
Reeve J. Newsom	293
David A. Hefferman	292
Frank E. Winsor	294
Theodore L. Bristol	292
Scattering	1
Secretary.	
Frank J. Gifford	288
Treasurer.	
Frederic I. Winslow	296
Editor.	
Henry A. Symonds	297
Advertising Agent.	
Henry A. Symonds	299
Additional Members of Executive Committee.	
George H. Finneran	298
Frank A. Marston	298
Melville C. Whipple	299
Scattering	1
Finance Committee.	
A. R. Hathaway	295
Edward D. Eldredge	295
Stephen H. Taylor	294
Scattering	1

GUY C. EMERSON,
JAMES W. KILLAM,
JAMES A. McMURRAY,
Tellers

On motion of Mr. H. V. Macksey, duly seconded, it was voted that the above reports be accepted and placed on file.

The President. You have all heard the report, gentlemen, by which it appears that the persons named by the Nominating Committee have been elected. While it is not, of course, necessary to turn the meeting over to the new officers, they not taking control until the next meeting, I think the members will want to hear a few words from the President elect. I will call on Mr. Barbour. (Applause.)

Remarks by President elect F. A. Barbour

Mr. Barbour. Mr. President and fellow members, I sincerely thank you for my election. It is an honor of which any man may well be proud; it is also a responsibility and, at the present moment, I am more impressed by this phase of the situation.

In the Boston Society of Civil Engineers there is a requirement that the President shall deliver an address at the close of his administration and, personally, I think this a very good rule. It is a much safer course to follow — at least from the standpoint of the President. At the end of his term he is probably a much wiser man than when he comes into office and he can then state what should be done and leave it to his successor to do.

There is no question but that there is much work to be done in this Association, if we are to hold our place in the water works field. We reached the high point in membership in 1917 with 950. That was a climb of some 250 members in the preceding three years. We are now down to 750, or in other words, we have lost 200 members in the last five years. From the 1921 list it appears that only 110 cities and towns in Massachusetts are represented in this Association, while there are in the State somewhat more than 200 water works. Only 200 men are listed in our total membership as superintendents or foremen and this number includes, in many instances, more than one member from the same city or town. Probably not more than one-third of the superintendents of water systems in Massachusetts are members of this Association, and right here is the weak point in our appeal to the public officials and to the public.

Roughly classifying the membership — sixty per cent are listed as engineers; twenty five per cent as superintendents and foremen, and the remainder as commissioners and miscellaneous. Including the engineers who are in charge of particular works, about fifty per cent of the members are engaged in the actual operation of water systems.

The point to be noted is the small percentage of superintendents and, in my judgment, this condition demands serious consideration. If we had completely sold the value of this Association to the public, it would not be possible for a man to become a superintendent in New England without first qualifying as a member of this Association. This brings up the questions of Corporate membership — such as is found in the American Water Works Association — and the possibility of convincing more public authorities that the expenses of the superintendent, in attending our meetings, should be paid.

There can be no question but that we should be able to maintain 1200 — 1500 members, without including any floaters who are drawn in as the result of some special drive and then later drift away. With a larger membership a much better Journal can be furnished and with a

better Journal we will more surely hold our membership, because the Journal is the greatest single factor in determining the future growth and welfare of this Association. Twenty per cent of our membership live beyond 500 miles; fifty per cent live beyond 100 miles and less than one-third live within 50 miles of Boston. To probably three-quarters of our members the Journal is the only return for their investment. Further, the preceding figures illustrate the fact that we are not a local organization: our membership is national and international, and our program should be planned accordingly. We should keep step with all processes and improvements in water treatment, without regard to their particular value under New England conditions, and we should coöperate with the American Water Works Association in their work of standarization.

Just a word to reinforce what the editor has said in reference to use of the advertisements in the Journal by the members. In my judgment, every man here, when ordering any materials, should refer to our Journal, and in his correspondence with advertisers he should make known this reference to the Journal. If the manufacturers can be shown that there is a direct response to their investment in our publication, a greater income from advertising will be obtained, and with increased income a better Journal can be provided.

I think I have said enough; I thank you. (Applause.)

Address by the President.

Mr. Sherman. For the address expected of the retiring President I have prepared to give you something a little in the nature of a technical paper rather than much comment upon the Association, although I would like to preface my paper by some few remarks, as probably should always be the case with a retiring President.

It is very easy for a man in laying down his position to look back and think over the things he ought to have done, and has not. There is an immense amount of work that a President of this Association can do, and perhaps I should say ought to do, and I am probably safe in saying that most, if not all, of my predecessors at the end of their terms have had much the same feeling that I have, which is that we have not begun to accomplish a tithe of what we ought to have done.

During the year the first consideration, the one that comes quickest to mind, is of course the change in membership, and it is somewhat disappointing, although not altogether surprising, if we realize, as we do from the Secretary's report, a net loss of 44 members in the year, in view of the increase in membership dues by fifty per cent which took effect in the year 1921, and I am inclined to think on the whole that is rather a less loss than we might naturally have expected, and that while it is disappointing it is not nearly as bad as it might have been.

Nineteen hundred and twenty-one marks the first year of the Association when we have attempted to govern its finances by a budget adopted in advance. The budget, including a recommendation for increased dues, was adopted late in 1920, and became applicable for the year 1921. For the first year I think the Association has been remarkably successful in that its total expenditures have very closely coincided with and been slightly under the amount allowed by the budget. Only two slight modifications of the amounts were found necessary. In two items the expenditures slightly exceeded the amounts estimated at the beginning of the year

The budget laid out for the new year, as Mr. Barbour has told you, includes a proposition to spend more money on the Journal than has been thought possible during the year past. The Journal, of course, is the most important single thing that the Association has. It is always a source of regret to do anything which cuts down the value of the Journal, and yet with the financial condition with which we were faced, especially with the extremely high cost of printing work of all kinds, it was absolutely necessary during the past year to economize radically in that direction. It has been done, and successfully done, but with the disappointment that we have not given you in print all we would have liked to do. Another year Mr. Barbour's administration will be able to do better, and we hope that each succeeding year will show greater improvement in the Journal.

Our losses in membership have been particularly marked. Among our honorary members we have lost by death four out of fourteen. The deaths of the honorary members were: Hiram F. Mills, William T. Sedgwick, George A. Stacy and Fred W. Shepperd, — two of them past presidents of the Association.

We have had during the year the most unusual experience of a bequest, one of our honorary members — Hiram F. Mills — having left in his will the sum of $1000 to the Association. The bequest has not as yet become available, but presumably will sometime during the coming year.

(Mr. Sherman then read a paper entitled "Some Observations of Water Consumption.")

MR. GEORGE A. CARPENTER.[3] Mr. President, there is one matter that I would like to bring to the attention of the Association before we adjourn. As I have listened to the report of the Tellers of the election I wondered if we were not allowing to pass by us without due recognition a fact of which we ought to take notice. When a member of this Association completes a long period of faithful service I think some notice should be taken of it. Today marks the close, if I am correctly informed, of nearly a quarter of a century of active, faithful service by one of our older members. I allude to Treasurer Bancroft, — one of the men who

[illegible] R. I.

has always been present at the meetings, who has been faithful and conscientious in the performance of his duties to this Association over a long period of years.

Mr. President, I would like to move a rising vote of thanks in recognition and appreciation of that term of faithful service by our Treasurer.

(The motion was immediately seconded by a number of the members, and the entire company stood amid applause and cries of "Speech.")

THE PRESIDENT. Mr. Bancroft, you are officially thanked.

REMARKS BY MR. LEWIS M. BANCROFT.

MR. BANCROFT. Mr. President, and members of the New England Water Works Association: It is true I have served you to the best of my ability for twenty-three years as Treasurer, but it has been with great pleasure that I have filled that office. I somewhat regret that it is necessary for me to retire at the present time; it is of my own election. I feel it is for the benefit of the Association that I should retire at this time, because I expect to be away considerable of the time, and the Treasurer or any other officer of the Association should be where he can attend to his duties. I sincerely thank you for your appreciation of my services. [*Applause.*]

THE PRESIDENT. If there is no further business the meeting now stands adjourned.

(*Adjourned.*)

FRANK A. BARBOUR,
President of the New England Water Works Association
1922

New England Water Works Association

ORGANIZED 1882.

Vol. XXXVI. June, 1922. No. 2.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

A HISTORY OF THE CORROSION OF THE 36-INCH STEEL FORCE MAIN AT AKRON, OHIO.

BY G. GALE DIXON.*

General Remarks.

In the choice between the use of cast-iron and of steel-plate pipe for large water-supply mains, the element of least certainty is the depreciation to be expected in the steel pipe due to corrosion.

We are all familiar with certain classic cases of corrosion, the most thoroughly described of which was that at Rochester, N. Y.; but a great many cases must exist of which little or nothing is generally known — unfortunately, for the light which they might throw on a most perplexing subject.

We are told that the only salvation is absolutely to prevent the steel-plate from coming in contact with ground-water, yet we all know of steel pipe imperfectly coated which has lain in wet clay ground for years without trouble of any sort.

To date we have a background of corrosion of steel pipe under various sets of conditions approximately as follows:—

(1) *Ground-Water Corrosion.* I have heard of severe corrosion occurring on steel pipe at stream crossings in the Alleghenies due to mine drainage carried by the stream.

(2) *Corrosive Soil.* Notes have recently appeared in the technical journals commenting on the corrosion of cast-iron pipe in alkali soils of Western Canada.

(3) *Rapid Localized Corrosion with the Passage of Relatively High Electric Current.* The most striking case of this effect occurred at Pittsburgh, Penn., where Mr. E. E. Lanpher reports that stray electric current amounting to about 2 000 amperes following a new 36-in. steel pipe to the vicinity of a power house, cut through the $\frac{3}{8}$-in. plate within 90 days after putting the pipe in service. This condition was corrected by connecting

*Chief Engineer, Bureau of Water Works Improvement, Akron, Ohio.

the pipe with the negative bus of the adjacent power house, with slight total damage.

(4) *Corrosion in Salt Marsh.* At Atlantic City, N. J., cast-iron, steel-plate and wood-stave pipe were successively destroyed where the lines ran for three miles across salt marsh, the corrosion of the metal pipes and of the steel banding of the wood-stave pipe occurring about the upper portion of the circumference where air, water and vegetable matter met. Stray current was credited with no hand in the work, and the final measure in meeting the condition was the construction of a cast-iron line supported above ground by concrete piers. *(70 Engineering News, 1046.)*

(5) *"Auto-Electrolysis" or "Self-Corrosion" in Ordinary Grounds.* At Rochester, N. Y., severe corrosion attributed to the combination of soil conditions and imperfections in coating and steel, occurred over several stretches aggregating about six miles in length in the 26-mi. pipe lines conveying water to the city from Hemlock Lake. Corrosion was apparently confined to wet clayey soil. The corroded portions were scraped and repainted, and the deeply pitted sections were patched by strapping new plates on the outside.

Stray current was credited with no hand in this. (John F. Skinner, "Steel Plate Pipe Conduit II," published by City of Rochester, 1913.)

The case at Portland, Oregon, was quite similar to that at Rochester. Serious corrosion was discovered over a two mile stretch of the 24-mi. Bull Run pipe line before the electrification of railways crossing and paralleling it. The line varies from 33 in. to 42 in. in diameter, and the plate from $\frac{1}{5}$ to $\frac{3}{8}$ in. in thickness. The worst corrosion was observed in very wet clay ground, relatively drier clay showing less active corrosion, and none occurring in sandy ground. Pitting was most concentrated on the sides and top of the pipe.

The line was laid in 1893-4, serious corrosion was observed by 1905, electrification of one adjacent railway was achieved in 1905-6 and of the other in 1913.

In 1914 little weight was given the electric railways in corrosion effect, though steps were taken to prevent damage by them. (Report of U. S. Bureau of Standards, "Electrolysis conditions on Bull Run Pipe Line, Portland, Ore., 1914.")

At both Rochester and Portland the soils and ground-waters were regarded as of not peculiarly corrosive character.

The Akron Case.

The case which is our present subject falls in none of these specific classes:—

It is that of a 36-in. lock-bar steel force main 11 miles long at Akron, Ohio, which after five years service evidenced very severe corrosion in wet clay ground over a stretch less than a mile in length; mild stray current was

found flowing on the pipe and leaving it in the corroding area at a point three miles from the nearest trolley tracks, to follow a route of low resistance in the natural ground back to the equally distant power-house.

A case possibly closely parallel is commented on by Herman Rosentreter in the *American Water Works Journal* of 1917, in discussing a paper on Electrolysis by Prof. Ganz:—

"An electric railway running southwest from Paterson, N. J., is paralleled by a 42-in. main supplying Jersey City. A 42-in. and 48-in. main supplying Newark, N. J., intersects the railway and runs directly

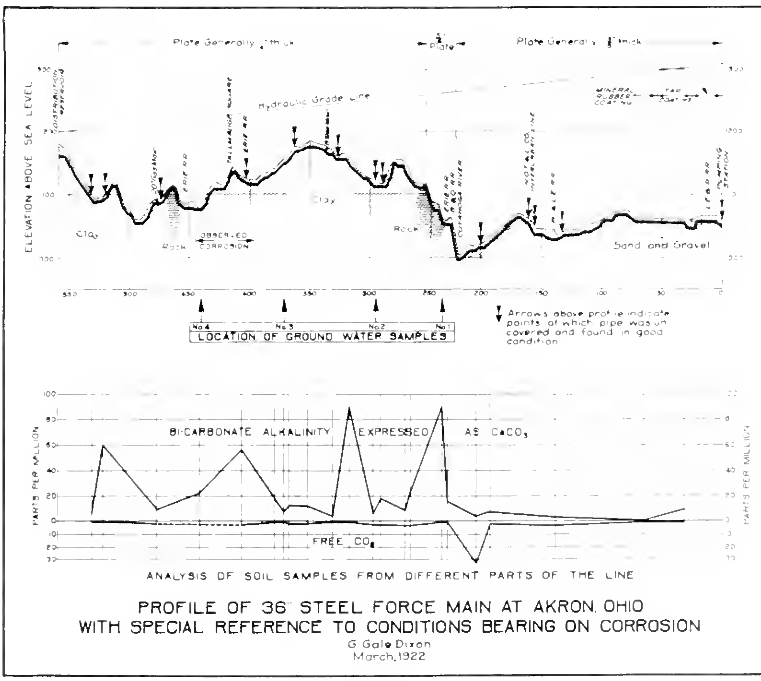


PLATE II.

away from the station supplying current for the cars. A leak was reported in the Newark main in a swamp about 3½ miles from the railway crossing. Investigation showed that the main was carrying 20 amperes at the break and only 2 amperes several miles beyond, and tests made on the main when the cars were not running showed that there was a slight current in the reverse direction, thus showing that stray electric currents are found about eleven miles from the power station."

General Description of the Pipe Line.

This pipe line was constructed in 1913-1914 under the direction of F. A. Barbour and E. G. Bradbury, Consulting Engineers for the City of Akron; a most thorough-going supervision was maintained on all processes, from the records of which much of the following matter is drawn.

As indicated in plan on Plate I (following this paper) the line lies almost straight to the northeast from the city limits to the pumping station, crossing the Cuyahoga River at a point somewhat more than midway of its length.

It runs through open farming country for the most part, the portion south of the river-crossing following a country road except for a detour to avoid a high knoll, while the northerly portion is laid in private right-of-way through the fields.

It will be observed on the profile of Plate II that the terrain traversed by the line differs markedly both in topography and in geological characteristics on the opposite sides of the river: To the north of the river the line follows quite closely the water-shed line of a gently sloping surface, and is laid practically in its entirety in sand and gravel, with occasional admixture of small proportions of clay; while to the south of the river it climbs through the more steeply rolling clay ground classed on the geological maps as the northerly edge of the "coal measures," encountering a little shale rock and crossing numerous small drainage channels, the largest of which is in the corroding area just to the southwest of Tallmadge Center, and drains country extending a mile back of the pipe-line.

The pipe was manufactured by the East Jersey Pipe Co. at Paterson, N. J., of plates ranging generally in thickness from $\frac{1}{4}$ inch at the southerly end of the line to $\frac{3}{8}$ inch at the northerly end. In cases of heavy cover over the pipe, thicker plates were used.

The plates are of open-hearth steel, approximately the grade of "Flange Steel," rolled by the Carnegie Steel Co.; mill tests compared with specification requirements as follows: —

	Specified Limit	Range of Test Results
Carbon		0.12 to 0.20%
Phosphorus	0.05%	0.01 to 0.038
Sulphur	0.05	0.025 to 0.04
Silicon	0.05	
Manganese	0.50	0.30 to 0.50

Ingot tops were cropped to sound metal, the discard reported by the mill inspector on 17 per cent. of the ingots averaging 27.3 per cent. by weight, and ranging from 20 per cent. to 80 per cent.

Mill and shop inspection was performed by the Pittsburgh Testing Laboratory, in continuous consultation with Mr. Barbour.

The plates were "pickled" to remove mill-scale by soaking for one hour in 10 per cent. sulphuric acid solution, followed by dipping three times in soda ash solution and an equal number of times in constantly changing water.

The finished pipes were thoroughly cleaned before dipping.

The specifications provided for coating the pipes by dipping in hot "coal tar pitch varnish," but this material was used on only about a half-

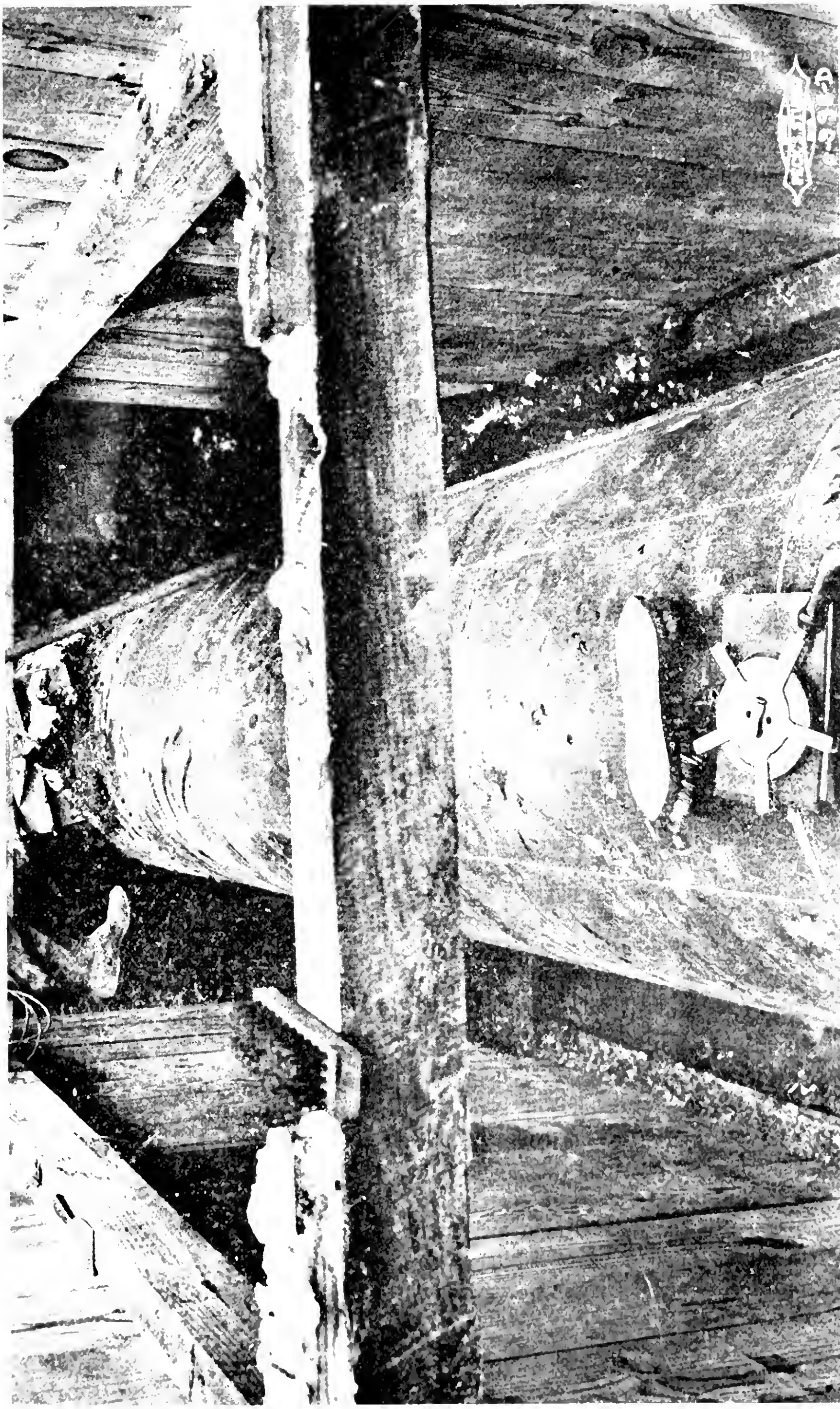


PLATE III. PHOTOGRAPH OF CORRODED STEEL PIPE AT STATION 110.

mile of the line owing to the difficulties encountered in so controlling the mixture and the temperature of bath and pipe that the resulting coating would neither flake at low temperature nor run at high. The remainder of the line was coated with "Pioneer Mineral Rubber," manufactured by the American Asphaltum and Rubber Co.

Delivery of the pipe on the ground was effected between November 21, 1912 and April 23, 1913. Pipe laying was started in May 1913 and completed in July 1914, so all of the pipes were exposed to the weather of practically a full winter season, while the tar-coated material between Stations 27 and 55 lay out through two winters.

A peculiarity noted in regard to the mineral rubber coating was the breaking down of the material on the exterior of the pipe where it had lain for long in contact with the sod, entailing considerable repair work.

In the spring and summer of 1914, inspection of the completed pipe showed considerable failure of the interior coating by coming loose, especially near the field joints; the line was thoroughly gone over, all loose coating removed, the steel cleaned, and two coats of commercial metal paint applied.

The line was put in service in August, 1915, since which date it has been in continuous service supplying filtered water to the city.

Corrosion Discovered.

In May, 1919, the pipe was uncovered at eight different points in wet clay ground south of the river-crossing, for the purpose of examining the condition of the exterior surface in connection with the preparation of specifications for a proposed paralleling line. In all cases the condition was found to be good; coating in some spots was brittle and in others thin or easily removed, but no pitting was observed nor rust under loose coating.

Several other inspection pits were dug later north of the river, exposing equally good conditions. The location of all these excavations are indicated on the profile of Plate II.

In November 1919, interior inspection of the pipe at a point about 1 000 ft. southwest of Tallmadge Square (Sta. 440) disclosed two holes eaten through the plate as the source of leakage which had been observed for some time on the surface, but which had been attributed to ground water. These holes were plugged from the inside and a sixty foot stretch of the line was then uncovered, showing a very severe condition of corrosion which is illustrated in the photograph in Plate III.

The chalk figures appearing on the pipe in Plate III register the measured depths of the larger pits in hundredths of an inch.

Three or four times as many pits were observed above the horizontal center line than below.

The corrosion phenomena inside and out conformed with what has been most excellently described at Rochester and Portland. Inside, the original

coating showed numerous blisters from $\frac{1}{8}$ to $1\frac{1}{2}$ inch in diameter, which when punctured and removed disclosed bright steel with a slight roughness in the center; in other places tubercles were found covering shallow "saucer shaped" pits. On the exterior, the "cup shaped" pits usually contained at the bottom a small quantity of material resembling white lead paste, though in some cases a pale brownish color was observed.

In several places long shallow pittings apparently followed where the coating had been scratched by a pick or shovel in back-filling, and in another case near the end of a pipe a similar condition had followed abrasion due to the cable sling with which the pipe was handled.

The excavation was held open for some time, and the conditions were observed by Mr. Frank Wilcox, Engineer for the T. A. Gillespie Co., Mr. W. R. Veazey, Professor of Chemistry at Case School of Applied Science, Cleveland, Mr. E. E. Lanpher, Engineer of Distribution of the Pittsburgh Water Department, and Mr. L. G. Tighe, Superintendent of Power for the local traction company.

A volt-meter test over the exposed pipe showed a considerable flow of current to be occurring on it.

To date a total of nearly 20 holes in the plate have manifested themselves by leakage appearing on the surface, all in the vicinity of Tallmadge Center (between the Erie Railroad at Station 400 and the brook at Station 445); these have all been plugged from the inside.

Comments by Professor Veazey.

The following extracts from a report on the matter by Prof. W. R. Veazey summarize his views:—

"The soil in which the Akron water main is laid, insofar as I have seen it, seems to consist of sand, clay, shale, ashes and various combinations of these. In general the soils are wet and have a tendency to hold water. Such soil conditions are very favorable to pipe corrosion either by galvanic action or by stray electric currents. Without going into detail, it is my opinion that a soil survey will be of little value except to confirm the statement I have just made that the general soil conditions are favorable to rapid corrosion of steel pipe."

* * *

"According to the geological map, you may expect to find glacial drift anywhere along the present pipe line except at Tallmadge, and for a distance of from one-half to one mile on either side of Tallmadge in the direction of the pipe line. At Tallmadge and vicinity you will likely find pyrite bearing shales and clays which are extremely favorable to corrosion of steel for the following reason: Pyrite is a sulphide of iron which is readily acted on by water and air to form the soluble salt ferrous sulphate (green vitriol) and also free sulphuric acid. The ground waters in the vicinity are nearly always impregnated heavily with the above salts and sulphuric acid. Since such ground waters are extremely favorable to the process of corrosion, any contact of the steel with such shales or clays or ground water coming from such shale or clay must be absolutely avoided."

* * *

"Steel, if kept dry, will not corrode. Although this condition probably cannot be absolutely maintained in a practical way, yet the more nearly it is approached, the longer will be the life of the pipe line. There are two ways of obtaining results in this direction, both of which should be applied: Efficient under drainage of the ditch in which the pipe is laid and a proper paint or protective coating for the steel."

* * *

"With reference to the kind of protective coating to be used on steel pipe: Insofar as my present information goes, the best protection is to paint the steel after it has been completely freed from mill scale, with red lead and oil, giving it two coats, and then after the pipe has been laid, an additional two coats of the same paint should be applied. I am of the opinion that the Bitumen coating which has been applied to your present 36-in. line is not beneficial in the long run because, although when new it may protect the steel from moisture, it has a tendency to become porous and spongy with age and then acts in the opposite way and retains moisture and thus actually stimulates corrosion. You will find evidence of this in spots where the Bitumen coating is blistered or raised up by the corrosion deposit underneath it."

* * *

"With reference to stray electric currents from power houses and power lines: Such currents should of course be eliminated by discovering their source and breaking the electrical connection, but this certainly is not the chief cause of corrosion on your steel line, even though it may be a contributing factor. Eliminate wet conditions along the line and this factor will drop out."

Electrical Conditions.

Mr. E. E. Lanpher, who has had a long experience in electrolysis and corrosion at Pittsburgh where much steel pipe is in use, was retained in an advisory capacity: owing to his many duties he was unable to follow the work actively in the field.

Referring again to the map of Plate I, it is to be observed that the city and interurban lines of the Northern Ohio Traction and Light Co., swing a rough arc to the northwest of the force main, the Akron-Kent-Ravenna line crossing it about a mile and a quarter beyond the river-crossing. The various substations are also shown, as well as gas mains.

It is to be noted that the location of observed corrosion is at a sort of focal point of all the obvious natural and artificial features of the locality — a high tension line passing right through the center of the affected area is not shown, as all thought of its influence was early discarded.

In December 1919 a milli-voltmeter survey of the pipe-line made with wires about 1 000 ft. long stretched between access-manholes indicated a current flow of about 20 amperes from Akron toward the corroding area at Tallmadge, and continuing on toward the point of crossing of the trolley line near Kent in about half that quantity; from the trolley crossing to the pumping station the current was much smaller in quantity and with quite rapid and uniform reversal of direction. The flow between Akron and the trolley crossing of course reversed at intervals, but there was evident a

definite flow toward the Kent substation. Following this survey, the traction company went over the rail-bonding of its interurban lines, which was in bad shape, and an appreciable improvement in conditions was noted.

At the suggestion of Mr. Lampher, a bond between the pipe and the rails near the Kent substation was inserted for test purposes, but was not put in regular use as it made the condition at Tallmadge worse.

Soil and Ground-Water Analyses.

Soil samples taken at the level of the pipe line were gathered from 23 test pits scattered over the length of the line, and the results of tests for "Free CO_2" and "Bi-carbonate Alkalinity expressed as $CaCO_3$" are shown graphically in the lower part of the profile, Plate II. Marked difference between the conditions on opposite sides of the river is here again apparent.

Ground water samples were also analyzed with the following results:

Sample No. (See Plate II)	1	2	3	4
Location	Sta. 239	Sta. 295	Sta. 370	Sta. 440
Character of Soil	Yellow Clay	Yellow Clay	Clay	Fill
Character of Vegetation	Road	Grass	Wheat	Road
Chlorine	10.0 ppm	5.0 ppm	6.0 ppm	10.0 ppm
Bicarbonate Alkalinity	276.0 ppm	3.5 ppm	5.0 ppm	128.0 ppm
Free CO_2	34.0 ppm	7.0 ppm	20.0 ppm	28.3 ppm
Nitrates	0.2 ppm	0.24 ppm	6.0 ppm	

Sample No. 4 was from the excavation for inspection of the corroded pipe near Tallmadge.

Repair of Exposed Pipes.

The two corroded pipes which had been uncovered for examination were finally carefully cleaned, the deeper pits flushed up with metal by the oxy-acetylene flame, and the pipes were painted with "Hermastic Primer" followed by "Hermastic Enamel" applied hot. The trench was under-drained and backfilled with clean sand and gravel.

Mr. E. E. Brownell's Report.

In August, 1920, Mr. E. E. Brownell, a consulting engineer employed by the Akron City Council to advise in the framing of a new traction franchise, was requested by the Council to review the situation in regard to electrolysis; he made a volt-meter survey of the city lines and the force-main, and the following excerpts regarding the force main are taken from his report of December 24, 1920:

"The electrolytic condition of the 36-in. steel force main is one of the most intricate that the writer has experienced in many recent years of experience. It is almost unbelievable how far distant the operation of the various substations influences the electrolytic condition of this valuable water artery."

* * *

"Everything is in favor of steel or wrought-iron force main construction, if the coating features are respected and due care and consideration be employed during such construction, so as not to permit the coating to become broken or abrased. This is the whole secret of steel force main protection. The electrolytic conditions should be corrected immediately upon the completion of the installation and all valves bonded over with heavy copper cables, so as to render impossible electrolytic action at an unintentional insulated pipe joint."

Report of Mr. E. E. Lanpher.

With all of the data as previously outlined at hand, and after several brief inspection trips on the ground, Mr. E. E. Lanpher, Superintendent of Distribution of the Pittsburgh Water Department, gave final advice under date of March 29, 1921, as follows:—

"No one of the soil analyses shows a dangerous content from a galvanic action standpoint. Practically the same statement is made in regard to the water analyses; for while it is true that the chlorine, nitrate and carbonic acid content would indicate a slight galvanic action, I am of the opinion that this action would not be serious where positive electric currents were absent. With such currents absent I would not hesitate to lay steel pipe under the conditions as shown by these analyses and with the expectation that a coating of concrete or extensive drainage operations would be a poor investment.

"There is no doubt in my mind that the soluble salts and the carbonic acid present in all the clay and in the coarser gravel soil will account for considerable electrolytic and accelerated galvanic deterioration where the soils are wet and in presence of positive electric current. Where the soil is dry these salts and acid do not appear to be present in sufficient quantity to account for great electrolytic damage under present positive current flows. I believe, however, that some deterioration will be found in the so-called dry soils, and it is certain that the positive current flows will increase as the power station loads are increased. In fact, it appears that in dry soils very little galvanic or electrolytic damage is in evidence at the present time:—not enough to warrant large expenditures for pipe coating.

"There is nothing in the soil and water analyses submitted to change my opinions under date of January 27th, 1921. I am still of the opinion that prompt action must be taken to eliminate all zones of positive electrical potential and that this action will render the steel pipe practically safe except possibly in the low ground near Tallmadge; and even at this point it would be advisable to defer coating operations providing electrolysis mitigation work could be started at once."

Investigations Directed by Crecelius and Phillips.

Owing to Mr. Lanpher's inability to spare the time to trace down and correct the complicated electrical conditions the services of Crecelius and Phillips, Consulting Electrical Engineers of Cleveland, were secured for this purpose early in March, 1921.

Mr. L. P. Crecelius is a member of the "American Committee on Electrolysis," representing the American Electric Railway Association,

and Mr. Victor B. Phillips served as his alternate on one of the sub-committees.

Mr. Phillips is covering the later features of the investigation in thorough manner in a paper which follows this, entitled "Mitigation of Electrolysis on Steel Force Main at Akron, Ohio," but to make the record here complete a very brief statement of results will be made.

Three series of tests were made on March 9, 10, 11; April 18, 19; and June 11, 1921. In all of these the engineering force of the Northern Ohio Traction and Light Co., under Mr. L. G. Tighe, Superintendent of Power, coöperated to the fullest extent, and at the second test Mr. E. R. Shepard of the U. S. Bureau of Standards also assisted with special instruments developed for the purpose by that organization.

Additional soil samples were also taken and submitted to the U. S. Department of Agriculture and to the Bureau of Standards for analysis.

The first two tests indicated mild stray current flowing on the pipe line toward Tallmadge from both ends, leaving the pipe in the corroding area, to follow some line of low resistance in the ground. The Northern Ohio Traction & Light Co. during the months of April and May, succeeded in putting its system in electrical balance with the force main by re-bonding its tracks in the vicinity of the Gorge, High Street and Brittain substations, and installing an insulated negative feeder on North Hill. This balanced condition was demonstrated by the tests of June 11, and the following quotation from Crecelius and Phillips' final report of June 23, 1921, gives a full summary of their conclusions:

(1) "That electrical conditions on the system of the Northern Ohio Traction & Light Co. are at this time so balanced as to eliminate the presence of current in serious quantities on the steel force main.

(2) "That there exist no geological formations that may serve as a natural battery with resultant galvanic currents.

(3) "That there is no danger from soil corrosion.

(4) "That there exist local galvanic currents due to presence of scale and also possibly to differences in the composition of the metal; and that the mains should be inspected from time to time to determine the seriousness of such local galvanic currents.

(5) "That periodic tests to determine current flow on force mains should be made in the future and that permanent test stations for such measurement may be installed to advantage.

(6) "That conditions are such as to permit the use of steel pipe without unusual danger (especially inasmuch as cast-iron pipe has already been laid in the dangerous area near Tallmadge)."

Construction of Paralleling Line.

The investigations as outlined were of especial urgency and importance in connection with the determination of policy to be pursued in connection with the construction of a paralleling 18-in. line demanded by Akron's rapid growth.

Before the corrosion at Tallmadge had been discovered, the second line had been constructed of lock-bar steel pipe from the city to the southerly end of the corroded portion.

In 1920 the northerly four and a quarter miles from the river-crossing to the pumping station was also built of steel, as by that time a firm belief had been established that there was nothing to fear in that part of the line. During the same season start was made in laying about 0.9 mile of paralleling cast-iron pipe through the corrosion area.

Before the contract was advertised, in the spring of 1921, for the remaining 3.2 miles from Tallmadge Station to the river-crossing, practically final conclusions of the investigations herein outlined had been reached, and this portion was constructed of steel.

All of the steel pipe in the second line was coated with "Hermastic Pipe Dip."

Some Questions.

Would not a thorough-going compendium of steel pipe experience, gathered through the agency of one of the Water Works Associations, be well worth its trouble?

In the recent past, the excess cost, in the ground, of large cast-iron pipe over that of steel-plate pipe has ranged around 50 per cent., even in the East; but this handicap will probably be materially overcome in the near future and the expectancy of life of steel will have to be more closely estimated.

If such a digest were undertaken, special consideration should be given to uniform graphical representation of the surrounding conditions bearing on corrosion.

Another item worthy of a digest is the sudden rupture of large pipes, both cast-iron and steel; breakage of cast-iron pipes has been quite fully covered at Detroit, Cincinnati and New York, and occasionally we hear of similar occurrences in steel pipes. Freedom from such rupture is commonly credited as one of the strongest points in favor of steel, but we should have a history of the subject on record.

There are various questions in the design of steel pipe lines which are still somewhat open:—

(1) Location of justifiable use — in the country only, or also for primary feeders in the distribution system of the city?

(2) And in the country, does the saving in cost of acquiring private right-of-way justify the laying of pipe in a convenient highway, with its attendant later troubles in repair?

(3) What of water hammer? Very definite policies are laid down for cast-iron pipe on this point.

(4) For what condition should air valves be proportioned?

(5) The theoretical analysis of a pipe to withstand internal water pressure is simple, and safe depths of cover for given diameters of pipe and

thickness of plate have been worked out. But in various places we see steel pipe used at a minimum plate thickness of $\frac{1}{2}$ inch, selected purely on the basis of general judgment. Do the uncertainties justify the narrowing of limits of plate thickness down to conform somewhat with the various classes of cast-iron pipe?

(6) Should a steel pipe line be rigidly anchored, or should it be left free to "breathe"?

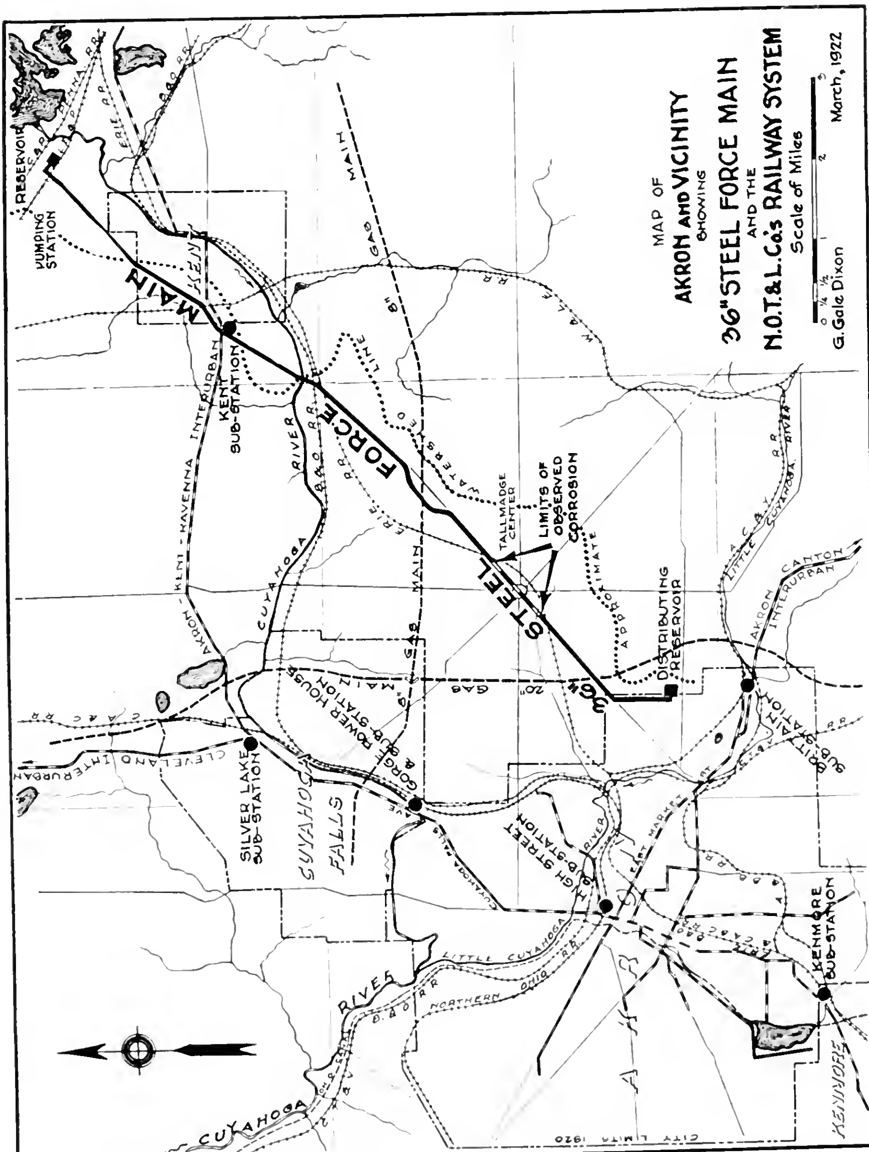


Plate I.

INVESTIGATION OF ELECTROLYSIS ON STEEL FORCE MAIN AT AKRON, OHIO.

BY VICTOR B. PHILLIPS.*

[*Read March 14, 1922.*]

INTRODUCTION.

In his paper before this meeting, Mr. G. Gale Dixon has outlined in a general way the history of the Akron Steel Force Main and the conditions which finally led to the retention of the firm of Crecelius & Phillips for the purpose of investigating the electrolytic conditions. The map on page 169 shows the 36-inch steel force main leading from the Earlville Pumping Station to the reservoir in the city of Akron, a distance of about eleven miles, and the location of the electric railway tracks, substations, gas mains, steam railroad tracks, and the principal city water main connections to the force main. Rather serious corrosion of the main had been discovered immediately west of the town of Tallmadge and at no other place. It will be noted that this point is more than three miles from the nearest electric railway tracks. It is also at considerable distance from either of the large gas mains that might possibly have been contributing factors. The town of Tallmadge comprises only a few houses and there is nothing in the town in the way of underground structures or electrical circuits that might have had some effect upon the force main. In a word, the corrosion was found at perhaps the one point on the main where it might least have been expected. For these reasons it was not at all apparent at the outset that the corrosion was due to electric railway current, and it was necessary to carefully consider all of the possible causes other than railway stray current. The case is distinctly unique, and the questions considered and the procedure followed in diagnosing the cause of corrosion and providing for its correction are, therefore, of more than ordinary interest.

In studying the case, the following causes of corrosion were investigated:

(a) Railway Current

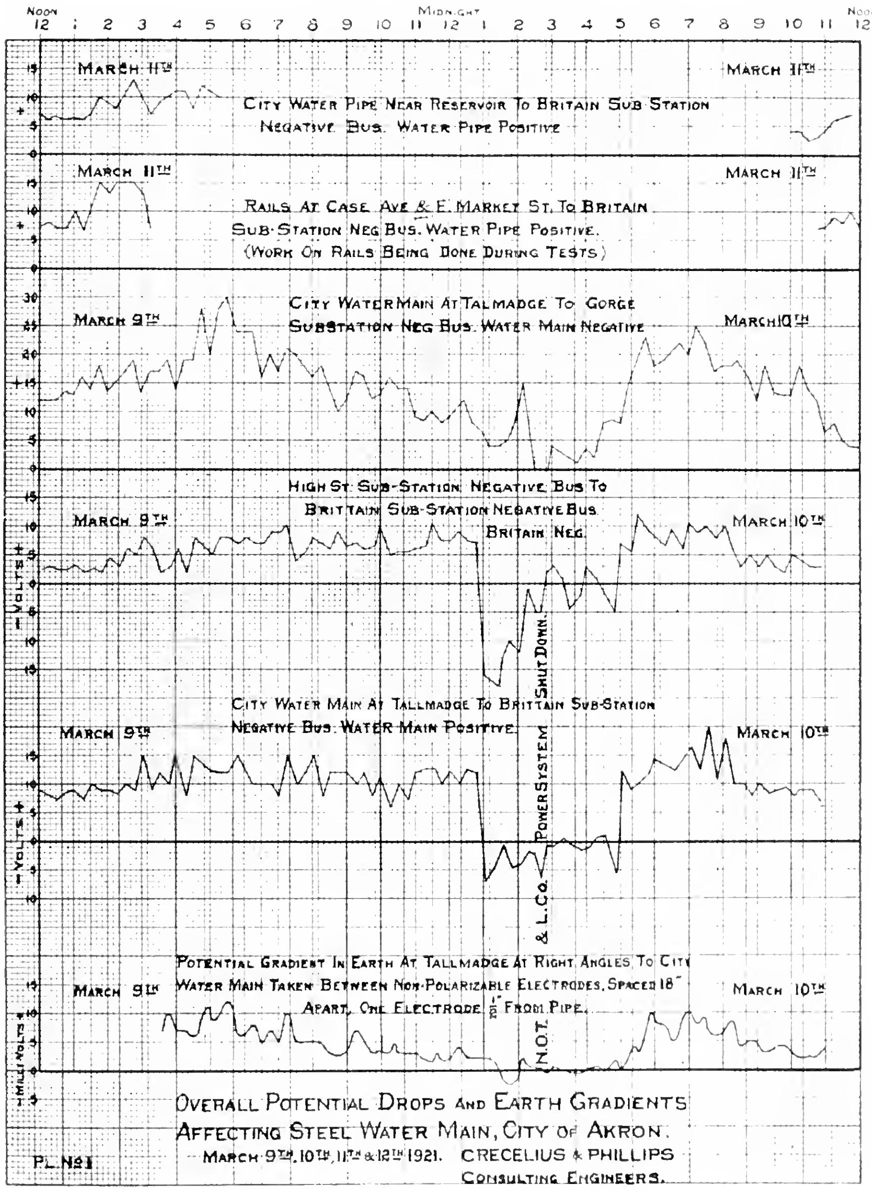
(b) Soil Corrosion

(c) Small Local Galvanic Currents.

* Of Crecelius & Phillips, Consulting Engineers, Cleveland, Ohio.

Railway Current.

Preliminary tests upon the force main showed that current was flowing away from Akron in the direction of Tallmadge to the extent of about 20



amperes at the time of the railway peak load. It was also found that there was some slight flow of current from Kent toward Tallmadge, although this current frequently reversed direction. Potential readings were taken be-

tween the force main and all metallic structures crossing it, viz: two gas mains and several railroad crossings. These voltage drops were found to be small, of the order of one volt or less, and apparently independent of the railway load and the magnitude of current on the main. It was, therefore, concluded that these structures had no bearing on the case.

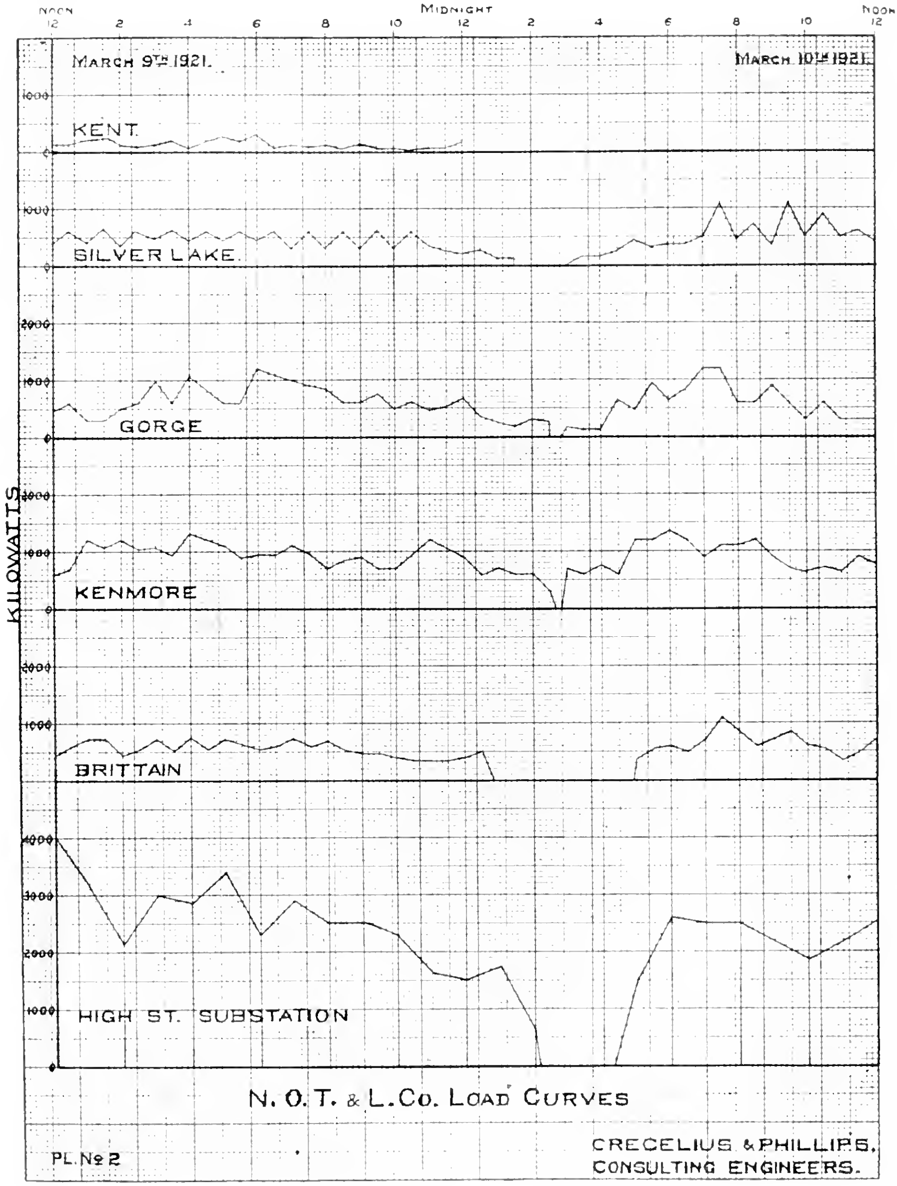
In order to determine the potentials causing the flow of current on the force main, voltage measurements were taken for 24 hours between the several railway substation negative busses and the force main at Tallmadge and at the Akron end. By means of these voltage readings it became possible to locate the point of minimum negative potential and thus to establish the path of the current. These readings are presented graphically on the accompanying curve sheet. They show that the negative bus at the Gorge Substation was the most negative point in the area under consideration. This fact served to indicate that the current which was apparently leaving the force main near Tallmadge was returning to the Gorge Substation. This fact, however, in itself could not be considered as conclusive evidence, inasmuch as it appeared unlikely that there was sufficient voltage difference to cause this current to flow directly across country for a distance of more than three miles.

In order to get a direct indication of the flow of current from the main into the earth in the locality of the corrosion, a 24-hour record was taken of the millivolt drop between two non-polarizable electrodes buried in the ground about eighteen inches apart and at right angles to the axis of the main, with one of the electrodes very close to but not touching the main. This potential gradient record is shown at the bottom of the curve sheet referred to above. It will be noted that the characteristic peaks and valleys of the curve, showing the voltage drop between the water main at Tallmadge and the Gorge Substation negative bus, are quite regularly co-incident, the only exception being between 1.00 A. M. and 2.00 A. M., when the High Street Substation negative bus became temporarily the most negative point on the system. At this time the flow of current in the earth near the force main reversed, as might reasonably have been expected. This information showed quite conclusively that there was a flow of current off of the force main in the Tallmadge area and that this flow was a function of the potential drop from the force main to the Gorge Substation negative bus.

A study of the geology and topography of the country between Tallmadge and the Gorge Substation disclosed the fact that there was an almost continuous low resistance path, due to creek beds and wet ground. The current was simply following this path.

Having established the fact that there was a measurable flow of current off the force main near Tallmadge directly across country to the Gorge Substation, it was then necessary to determine the reason for the current taking this long, roundabout and comparatively high-resistance path. At least one contributing cause was found to have been in the

rather long stretch of poorly bonded track between the High Street Substation and the Gorge Substation. Thus, a certain part of the power originating in the Gorge Substation positive feeders had to find its way back



to the Gorge Substation negative bus by another path than the high-resistance rail circuit. This increment of current then followed the tracks of the railway system into the High Street Substation and thence through a bonded connection into the city water system and into the steel force

main. It should be pointed out that the route followed by the railway, as well as the City of Akron, is all on high well-drained and consequently dry ground, so that there were no low-resistance ground paths by which this current might have taken a shorter route to the Gorge Substation.

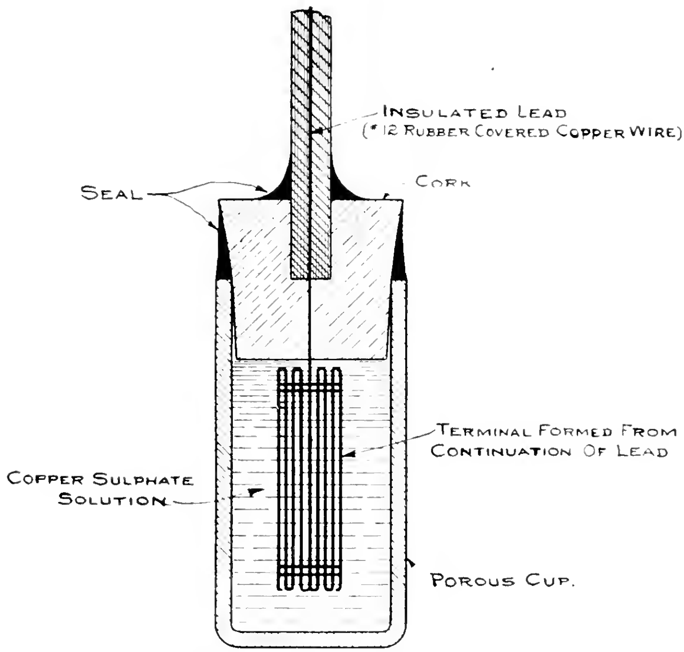
With the above information, it became a simple matter to eliminate the flow of current on the force main. This was done by thoroughly bonding the tracks, especially in the locality mentioned above, and by running out a negative feeder from the Gorge Substation, in the direction of High Street. This feeder was not tied to the tracks for a distance of three thousand feet, although the connection between the Gorge negative bus and the track at the substation was retained. In this way a part of the return circuit drop was transferred to the negative feeders with the result that the potential of the tracks was raised considerably. These *mitigative* measures served two purposes, viz: to provide a metallic return circuit of higher conductivity, and to reduce the potential drop between the force main at Tallmadge and the Gorge Substation. In this way an electrically balanced condition was obtained, and although the flow of railway current has not been entirely eliminated, it has been cut down to a negligible value, with continually reversing polarity.

Testing Equipment and Procedure.

Due to the unusual conditions that prevailed, it was found necessary to exercise extreme care in the testing methods employed. For the purpose of taking millivolt drops along the force main, special contactor rods were made up. These rods were of steel and had a twist drill welded to one end. The rods were heavily insulated with shellaced tape the entire length up to within one-eighth of an inch of the drill point. The purpose of this insulation was to prevent contact with the earth and thus to eliminate any galvanic potentials that might be set up as a result. The force main was reached by first driving down heavy bars and then inserting the contact rods in the holes made in this way. It was found necessary to use a millivolt meter of extremely high resistance in order to get accurate current determinations. Inasmuch as the potential readings along 15 feet of the main were but a fraction of a millivolt, due to the size of the main and the small magnitude of the current, it is apparent that these readings had to be taken with great care, since the slightest galvanic potentials would have completely vitiated the results.

The non-polarizable electrodes used in this work are of some interest. It was necessary that these electrodes be of low resistance. This was obtained by the construction shown in the accompanying cut. It will be noted that this type of non-polarizable electrode is very simple to make up. The copper terminal is formed from the lead wire by removing the insulation and doubling the wire back a number of times in order to get a large contact surface. In this way a welded or soldered joint is eliminated, the

latter type of joint being particularly undesirable because of the galvanic or thermocouple effects. The lead wire is brought out through a cork stopper, the junction being made watertight. The container, in which is placed a saturate solution of copper sulphate, is nothing more than an ordinary porous cup such as that frequently used in the laboratory.



NON-POLARIZABLE ELECTRODE.

Mr. Burton McCullom of the United States Bureau of Standards has recently developed a new instrument for measuring directly the flow of current in earth and also the *resistivity* of earth. After preliminary tests had been conducted on the Akron force main, as previously indicated, we requested the use of this instrument of the Bureau of Standards, and Mr. E. R. Shepard of the Bureau went to Akron and checked our observations by means of the new current measuring instrument. In connection with this instrument a very high-resistance millivolt meter (2 500 ohms) is used. This millivolt meter was used to check the current observations on the force main.

The recording millivolt meter used with the non-polarizable electrodes was of comparatively low resistance, so that the millivolt readings are not accurate, at least for the determination of actual current. They do, however, serve the purpose of showing the variations, which was all that was desired.

Soil Corrosion.

With a view to determining the possible existence of soil conditions that would corrode the steel pipe, a number of soil samples were taken in the affected area and sent to the Bureau of Soils of the United States Department of Agriculture. It may be of interest to quote from a letter received from Mr. Milton Whitney, Chief of the Bureau of Soils, in which are reported the results of soil analyses.

The analysis of the water soluble constituents follow:

Total Solids at 110°	670	parts per million
Total Solids ignited	560	parts per million
Total Solids by electric bridge	570	parts per million
CO_2	None	
HCO_3	175	parts per million
Cl	3.5	parts per million
SO_3	208	parts per million
CaO	200	parts per million
MgO	39.5	parts per million

"The amount of iron in solution was too small to be accurately determined, but the drying of the soil would probably oxidize and precipitate any iron that might have been in the solution when the sample was taken.

"There were no sulphides in the soil that we could detect, nor any indication of an acid condition in the soil solution other than that caused by carbon dioxide.

"There is an unusually large amount of calcium sulphate in this sample of soil and more magnesium sulphate than normal. The presence of this abnormal amount of soluble salts would accelerate soil corrosion and also electrolysis by giving a higher conductivity to the soil solution."

With a view to getting still further information on the subject of soil corrosion, Mr. Whitney's letter was quoted in a letter addressed to the Bureau of Standards, in reply to which the following was received:

"I do not know that we can add anything to Mr. Whitney's comments relative to the corrosive action of this soil. Until a large number of corrosion tests have been made on soils of different compositions we could only guess as to the effects of the chemicals contained in the Akron soil. So far as our knowledge goes, they do not appear to be of a particularly corrosive nature. More than a year ago we proposed to the Research Sub-Committee a program along this line, but nothing has been done up to date as you know. It would require tests, in some cases, extending over a period of years and the Bureau will not be able to undertake them until more funds are available.

"We believe that a resistivity measurement would throw more light on the questions of soil corrosion and electrolysis than will the chemical analysis. Not only is a high conductivity conducive to electrolysis, but it undoubtedly has an important influence on galvanic corrosion as well.

"We have found earths to vary widely in resistivity. Humus from New Orleans has a very low resistivity in the order of 800 ohms for one centimeter cube, while earth in this vicinity will vary from 5 000 to 15 000 ohms per centimeter cube. Ordinary clay soil will run from 1 000 to 4 000."

Soil samples were also sent to the Bureau of Standards for determination of resistivity. Mr. E. R. Shepard of the Bureau of Standards reported on these samples as follows:

"We have made electrical conductivity measurements on it with the following results: After removing stones and coarse matter the sample was saturated with distilled water. In this condition it had a resistivity of 3 890 ohms for 1 cm³. This soil appears to be, so far as resistivity is concerned, a normal clay soil with a resistance somewhat above the average for that character of soil.

Black loam from New Orleans had a resistance of about 600 ohms, and that from the downtown section of St. Louis about 900 ohms. Several samples of soil collected from Des Moines, Iowa, had an average resistance of about 1 800 ohms. Clay soil from Pittsburgh had a resistance of about 2 500 to 3 000 ohms. Philadelphia clay soil will run somewhat higher than these values, and the red earth around the Bureau of Standards has a resistance of 15 000 ohms and upward.

"As compared to other soils, therefore, the Akron soil does not appear to be in any way unusual."

The above reports, both by the Bureau of Soils and the Bureau of Standards, showed, insofar as the matter was subject to determination, that there was comparatively little likelihood of soil corrosion. It should be pointed out, however, as stated in Mr. Shepard's letter, that the entire subject of soil corrosion is but imperfectly understood. It is not possible at the present time to adequately interpret soil analyses. There is also some difference of opinion as to methods of taking samples and making resistivity determinations, and even were accurate determinations possible, there is still a lack of understanding of the relation between resistivity and local galvanic corrosion. In a word, at the present time the most that can be done is to draw a very rough comparison between the conditions as they exist in a particular locality with the average of conditions determined elsewhere. Any conclusions so drawn here are at the present time very much open to question. There is at present no way of determining by an examination of the corroded metal whether or not the corrosion has been caused by stray currents, by soil ingredients, or by local galvanic currents. None of these statements, however, should be taken to mean that soil analyses and resistivity determinations are of no value. On the contrary, they are perhaps particularly necessary where the use of steel pipe is contemplated, for they will at least serve to show whether or not conditions are distinctly unusual and dangerous.

Local Galvanic Currents.

Local galvanic potentials are extremely difficult of determination. They may be due to one or more of a variety of conditions, such as: lack of homogeneity in the pipe metal (e.g., there may be spots in which the carbon content of the steel is considerably higher than it is in the surrounding steel) scale; the presence of particles of coke such as occur in cinders; structures

of cast-iron or other metal in the vicinity of the affected structure: close proximity to a coal measure. These galvanic potentials will, of course, vary through wide limits, and there is no apparatus by means of which they may be properly measured.

In the Akron case it was found that there was an appreciable galvanic potential between the pipe and oxide scale, the steel being positive to the scale. Millivolt readings taken between different parts of the pipe or between clean pipe and scale, or between ground and pipe, were found to be in some cases even greater than the readings across the two non-polarizable electrodes used in the earth current observations and those obtained along the main by which the current flow in the main was determined. From this it becomes evident that in all the tests involving small potential readings, it is absolutely necessary to guard against the effect of these local galvanic potentials upon the readings desired.

It will frequently happen that when back-filling after a pipe has been laid, cinders or other foreign matter from the surface of the ground will be thrown into the trench in contact with the pipe. The effect of this may easily be more serious than a heavy stray current. Many cases are known where a heavy cast-iron pipe has been completely destroyed in a few months by the action of cinders.

As in the case of soil corrosion, it is difficult to generalize on the subject of local galvanic action. The most that can be done is to make a careful search for the presence of foreign materials or earth ingredients or adjacent structures that may produce galvanic currents.

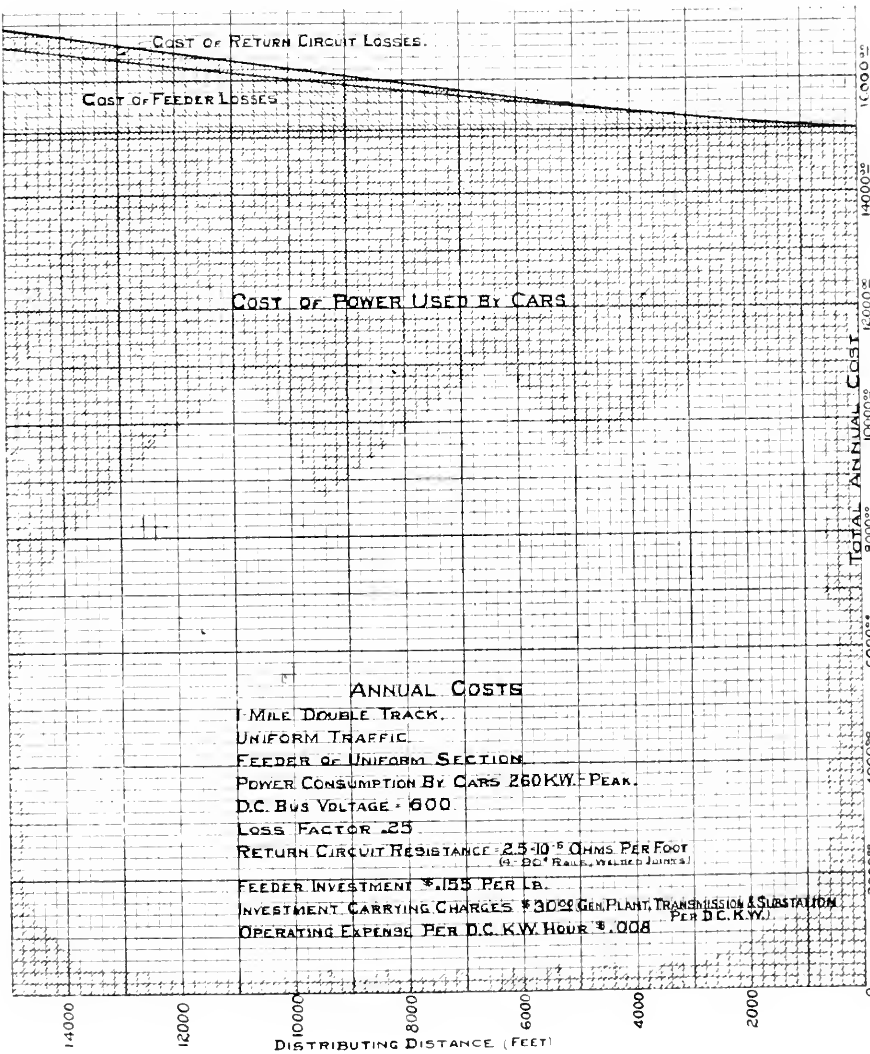
It may be noted at this point that the heaviest and most carefully applied coating is, under some circumstances, even worse than nothing so far as electrolytic corrosion is concerned. If there be a potential difference due either to railway stray current or local galvanic current there is a tendency for this current to seek the weak points in the coating and to concentrate. The result, therefore, may be a much more rapid corrosion than would take place if the current were more uniformly distributed over the surface of the structure.

Where there exists any doubt as to the possibility either of soil corrosion or of local galvanic action and the value of the pipe or other structure warrants the expense of excavation, regular inspection will prove the only satisfactory safeguard. This is particularly true of steel mains, inasmuch as they are much more subject to corrosion than cast-iron mains.

In the Akron case is it believed that the force main is reasonably free from both soil corrosion and local galvanic corrosion. Yet, here is a case where a very large investment, as well as the continuity of the water supply of the city of Akron, is involved. It would, therefore, be highly improper to assume that the question of soil and local galvanic corrosion has been settled once and for all. On the contrary, it should prove cheap insurance to make excavations from time to time at different points along the force main and observe carefully its condition.

Present Status of Electrolysis Question.

It is perhaps not amiss in a paper of this kind to say something of recent developments bearing upon the subject of electrolysis, caused by electric railway stray currents. This question has been very actively



studied for a number of years by all of the national public utility associations whose interests are affected. The American Water Works Association is one of these. The studies have been carried on by the American Committee on Electrolysis, in which these several interests are represented. The members of this Association are probably thoroughly familiar with the recent Report of the American Committee on Electrolysis. This report

represents the unanimous opinion of the representatives of all the different interests involved. It is undoubtedly the best text that can be found on this very live subject.

A matter of concern to the water companies and other pipe owning and cable owning interests is the study and development of railway distribution, and more particularly the automatic substation. Were it economically possible to install on a railway system a very large number of substations so that distributing distances would be cut down to, let us say for example, one mile or less, the track voltage drops that result in stray currents would be practically eliminated. The last two or three years have witnessed the advent of the automatic substation on a large scale. The principal justification of the automatic substation, or automatic substation combined with remote control, is to be found in decreased distributing distances, with the consequent saving in the cost of distribution and, what is also important, the reduction of stray currents.

At the present time it is impossible to generalize as to how far the matter of decreased distributing distances may be carried. The reason for this is that automatic control has not yet been standardized and the efficiency of the automatic substation varies through wide limits for different methods of operation. It has not been possible to determine just how some of these problems may best be worked out. Consequently, without more precise data on these points, it is difficult to make a satisfactory analysis showing how far this development may be carried.

The main question involved may be illustrated by means of the accompanying chart. This chart shows the component parts of the total cost of supplying a given amount of power to electric cars for a range of distributing distances. It will be noted that as distributing distances increase, the cost of distribution becomes a larger and larger part of the total cost of power. Consequently it follows that on interurban lines where distances are great, the reduction of distributing distance is a matter of more importance than in the case of city systems where distances are smaller. The automatic substation, therefore, finds its particular field at the present time on interurban railway systems or on long electrified steam roads.

It is perfectly safe to predict that the future will see a marked reduction in distributing distances on interurban lines as well as some reduction on city lines, although in the latter case it will of course be smaller. The electrolysis problem is therefore being solved to some extent by those developments in engineering leading to the more economic distribution of power. As these developments continue and the electric railways of the country profit by them, it is quite likely that the whole difficulty of electrolytic corrosion from stray currents will cease to exist.

DISCUSSION. (JOINT.)

DIXON AND PHILLIPS PAPERS.

THE PRESIDENT. We have listened to two very interesting and valuable papers and I hope that the discussion will be up to the same standard and that we shall justify the courtesy of Mr. Dixon and Mr. Phillips in coming from Ohio and talking to us this afternoon.

On my right I see Major Leisen, ex-President of the American Water Works Association, and I think he might open the discussion. We are glad to have him here.

MAJOR THEODORE A. LEISEN.* Mr. President, I came here for the purpose of listening to these papers, particularly the first one, — on corrosion,— and was very much interested in it.

I am hardly prepared to say anything that would add materially to what has been given here already. I laid some large steel pipe a number of years ago in Wilmington, Delaware, the first line of lock-bar pipe laid in this country,— and that pipe has suffered to quite an extent, principally from electrolysis. From the best knowledge that I have, based on a report received over a year ago, the general condition of that pipe was just as good as the day it was laid with the exception of those particular points where electrolysis had affected it. But this was not a condition that was peculiar to the steel pipe alone, as the cast-iron pipe in the same localities suffered practically to the same extent.

We are now laying steel pipe in Detroit, (a condition which we have been forced to by the excessively high cost of cast-iron) principally 42 and 48-inch sizes, but it is too early to say anything about results. The first pipe has only been in a little over a year, and of course it is too early to look for any change in condition.

The question of steel pipe seems really to narrow down to two factors, the coating, which is one of the most important things, and the character of the soil. First of all, the quality of the coating and the ability to get absolute adherence to the steel pipe, and proper protection of that coating in the field work. With all the safeguards that you can throw around the men who are handling the pipe,and all the instructions and orders that you can issue, it seems almost impossible to get the pipe from the cars to the ground, and then into the ditch, without materially damaging the original coating. The first trouble frequently is from slippage of the pipe on the skids of the cars. If the train in which it is hauled bumps around a good deal you will find that considerable of the bottom part of the coating is rubbed off at those points where it rests on the skids. Then too the chains and ropes used in lowering it are another important feature in causing abrasion. Too much stress cannot be laid on the fact that those abrased sections of the coating should be supplemented by extremely careful field painting. There is no question but what steel pipe is getting to be, and will become more and more, a factor in water works mains,

* Engineer, Board of Water Commissioners, Detroit, Michigan.

particularly on large lines and long lines, and it will be up to this and similar Associations and the members of the Associations, to study that question with a view to getting the very best results both in the coating and the handling for the protection of such lines as are laid from this time on. The second factor — character of soil — is of necessity a local one. If the soil is neutral no trouble should result, but acid soils should be thoroughly investigated before laying steel pipe.

I have been asked to present a paper on Steel Pipe before the coming convention of the American Water Works Association, and am rather in a quandary, with the short time between now and the date of the convention — May 15 — whether I am going to be able to get sufficient data together to present a paper that will really be of any value. If this paper could be postponed for another year it might be very interesting to try and obtain as complete records as possible of all steel pipe laid in the country, with reports on the condition of that pipe after years of service, and combine that into a fairly comprehensive report.

President Barbour. Many interesting questions concerning steel pipes are suggested by the papers of this afternoon.

In the first place, as stated by Mr. Dixon, it was originally planned to coat the Akron line with tar — the specifications requiring a straight run coal tar pitch and heavy coal tar oil to be used — the final results to be a coating tough and tenacious when cold and not soft enough to flow under summer heat. On about one-half mile of pipe, tar as specified was used, but, owing to the difficulty encountered in obtaining a coating that was not either too soft or too brittle and because of the inability of the manufacturer to get acceptable results and meet the required deliveries, the use of tar was given up and on the remainder of the line asphalt was used. As just stated, this change was made to facilitate delivery and should not be interpreted as indicating that the engineer of the work considered asphalt superior to tar.

The difficulty in the use of tar was in great part due to a wide range in the temperature to which the pipes were heated before dipping and to variation of temperatures in different parts of the same pipe. Asphalt will stand a wider range of temperature without apparent ill-effect than tar, and is thus favored by the steel pipe manufacturers who have no accurate control of the pre-heating.

Mr. Dixon has referred to the rapid deterioration of the asphalt coating and the necessity of extensive repair work before the line was put into service. This condition is chargeable in great part to the delay in laying the pipe owing to trouble between the primary contractor and the sub-contractor who did the excavation. The result of this disagreement was that the greater part of the pipes were exposed for many months to the weather — a most serious test for any coating — and, in my judgment, it does not follow that because the asphalt on the Akron line peeled off in sheets that this material should be generally condemned. On the other

hand, it is true that similar peeling of asphalt coatings have occurred in other new pipe lines, and it would be to the interest of the profession if more information as to these happenings were made public.

Mr. Dixon has also referred to the fact that the plates for the Akron line were pickled to remove mill scale. This was done by immersion in 10 per cent. acid at 100° F. for an hour, neutralizing in a soda bath and finally washing. The plates thus treated were silver bright when emerging from the final washing; and if there is any value in the removal of mill scale as a preventive of "self corrosion," the treatment of the Akron line went as far as is practicably possible in this direction.

Whether pickling had anything to do with the subsequent peeling of the coating may be debatable. After pickling a plate develops a smear of rust within a few minutes and, as fabrication and dipping of the pipes does not always keep step with the pickling, it may be that this accelerated rusting has a tendency to reduce the adhesion of the coating. Whether pickling to remove mill scale is worth while may be open to question.

It is to be clearly noted, however, that the corrosion of the Akron line — described in papers of Messrs. Dixon and Phillips — is not attributed to failure of the coating, or to soil conditions, or to local galvanic currents resulting from mill scale, or other causes of potential differences in the pipe. The rapid corrosion in less than one mile of the eleven miles of pipe line is charged to the effect of stray electric railway currents — the unusual condition being the great distance between the pipe line and the nearest electric railway tracks. The mitigative measures adopted involved the establishing of a more nearly balanced electric condition in the railway system so as to reduce the potential drop between the pipe line and the point in the railway system to which the current had been returning. It of course remains to be seen to just what degree these measures will eliminate further corrosion. The experience described should not be interpreted as an argument against the use of steel pipe.

Mr. Allen Hazen.* There is no doubt about the utility of steel pipes in large sizes in water works service. One of the most fundamental points of difference between steel and cast-iron is that steel is ductile while cast-iron is brittle. Because of its ductibility, the steel pipe will stand, without appreciable damage, pressure from soil and unequal loading that would destroy cast-iron pipe. In many places the added safety against rupture secured by the use of steel is a controlling reason for selecting it. The danger of breakage with cast-iron increases rapidly with the diameter. Steel pipe in large sizes is much safer.

Both cast-iron and steel corrode. Papers like the one that we have just listened to will help us in understanding this corrosion. We need to learn more about these matters, and we must find means to reduce corrosion and to prevent the excessive corrosion that sometimes occurs. In actual experience the excessive corrosions in actual lines of pipe through years

* Consulting Engineer, New York.

of service have amounted to only a small annual percentage of depreciation on the whole amount of such pipe in service.

I am sure that a careful examination of the oldest steel pipe lines in water works service would indicate a percentage of depreciation much lower than anyone would have thought probable when those lines were laid.

One of the causes of corrosion of steel pipe is the soil. That is, the soil in places contains some substance that accelerates corrosion of the outside of the pipe. A wet soil, and especially a soil that contains ground water with high mineral contents, makes corrosion more easy and rapid. In general a porous soil is believed to be a contributing factor, but some impervious soils are corrosive. Some times the pipe is laid and the first knowledge of the corrosive properties of the soil is obtained when corrosion of the pipe becomes apparent, but some conditions may be recognized in advance and guarded against. For instance, pipes commonly corrode on the outside where they cross salt marshes near tide water.

Corrosion of pipe by the soil may be prevented by surrounding the pipe with concrete. That adds to the cost, but so far as we know, it is a sure cure for soil corrosion, and if the trench is dug carefully for back fill with concrete it is possible to surround it with concrete at an expense that is not excessive.

Some steel pipe was so laid during the past year in the streets of a city in the middle west. It was surrounded by concrete at all places except where the natural soil was impervious clay, which was believed to be almost equal to concrete for protection. Steel pipe protected in that way may have a long useful life. It is certainly free from the danger of interruption of service by rupture — a danger which is always present with the largest sizes of cast-iron pipe.

When stray electric currents flow through steel pipes it is more often the cast-iron pipe and the services connected with it that suffer than the steel pipe itself. This is because the current most frequently leaves the steel through these attached lines. The author has described an unusual condition where the stray current left the steel pipe to go directly to the soil with attendant damage to the pipe.

Mr. Stephen H. Taylor.* Mr. President, a 48-inch steel pipe, 8 miles long, was laid in 1897 and 1898, in connection with the New Bedford Water Works, being put in service in 1899. The pipe was $^{5}/_{16}$ inch thick and coated with asphalt inside and out. It was lap-joint riveted pipe. It has been inspected internally several times since it was put in and found in as good condition as might be expected. There have been some tubercles and some blisters. If the blisters are broken a little corrosion is found under them.

In laying the pipe it was very carefully inspected, and wherever the coating was knocked off in transit or in handling it was very carefully put back. We had occasion last year to make an opening in that pipe for

* Superintendent of Water Works, New Bedford, Mass.

connecting with a 36-inch line. This is the first, and perhaps the best test we have had of its actual condition.

The outside of the pipe was in almost perfect condition when we uncovered it. It was in a gravelly soil — very wet but gravelly, and by just brushing it off and putting on a coat of black paint it looked almost like new pipe. The deepest pittings shown on the photograph I believe were about $\frac{1}{8}$ inch, or about $\frac{1}{3}$ of the thickness of the pipe. These are the small ones. The larger pittings are very shallow.

We feel that we have perhaps got about half, or perhaps a little more than half the life of the pipe at the present time. That is, we have had twenty-two years use of it so far, and we ought to get perhaps 15 or 20 years more.

President Barbour. Do you know what particular brand of asphalt was used?

Mr. Taylor. No, but the specifications are:

"The coating consists of best quality of California or Trinidad refined asphalt, must be durable, smooth, glossy, hard, tough, perfectly water proof and not affected by any salts or acids found in the soil, strongly adhesive to the metal, no tendency to become soft enough to flow when exposed to the sun in summer or become so brittle as to scale off in winter. Pipes thoroughly cleaned inside and outside and rust removed by brushing and scrubbing with a wire brush and diluted acid, followed by mopping or brushing with milk of lime or saturated solution of soda. The alkali used to be washed off and surface dried. Coating heated to temperature of about 300 degrees and pipes dipped, allowed to dry, then dipped again."

Mr. Henry A. Symonds.* Mr. President.—There are a few construction difficulties that I remember in connection with the 42-in. lock-bar steel pipe line built for the City of Springfield, about twelve years ago, on which Mr. Hazen was Consulting Engineer.

These matters perhaps did not come so much to the attention of the Engineering Department as they did to those of us in the Construction Department.

Regarding coating, the pipe had been dipped into a hot bath of melted pitch. When this was raised out of the pitch, it being immersed vertically, subsequent developments indicated that, on an occasional pipe, the hot pitch flowed to the lower section, leaving the upper as thin as tissue paper in some cases, while it was heavy and adhered tenaciously to the metal at the bottom.

The pipe was retouched by melting pitch and burning it in with a blow torch where the skid marks referred to by Mr. Liesen, occurred, but the difficulty relative to interior coating was not apparent until the pipe was laid in the trench.

It required going over the line several times, painting sections here and there, with hot pitch burned in by blow torch, before the trouble was entirely taken care of.

* Consulting Engineer, Boston, Mass.

Another difficulty which we had frequently in the actual construction, occurred in the sandy plains near West Springfield. Frequent spurts occurred from the riveted joints, and some of them remained even after calking. These spurts with the fine sand driven against the side of the pipe, in several cases cut grooves entirely through the metal. In some cases, I think, in less than twenty-four hours from the time water was turned on. In two cases long sections of pipe, laid through hollows, floated by the trench being flooded in a heavy storm, and the trench was washed partly full of gravel. As these sections had been riveted and calked it was a very different matter to get them back to grade.

Another difficulty which I think we barely escaped through good fortune, which has occurred in some other lines, was the collapsing of the pipe before the air valves were properly in place. There were 6-inch gates, which were to later receive regular air valves, for taking air into or allowing it to escape from the pipes, but during the testing period the plates pulled out of the lock-bar at one point for about 6 feet. That, by the way, was the only break that occurred in the twelve miles. I think this was under a pressure of something like 190 pounds. It occurred at a very low level as compared with much of the line, and the speaker happened to be near and opened one of these 6-inch valves. The whistling which occurred was equal to that of a locomotive, and continued probably for fifteen minutes, in which time the pipe was rapidly emptied. There was probably a mile and a half which was emptied by this break.

Those are perhaps the principal difficulties which we encountered in that construction. But I want to say that any one who starts to lay steel pipe and tries to use the methods employed in laying cast-iron pipe will find himself up against a great many troublesome problems.

Mr. Taylor. I might add to the New Bedford situation that we frequently test that pipe for leaks and have so far found it absolutely tight. Also at one time we were threatened with trouble from electrolysis and cured that by putting in a copper bolt and leading a wire back to the negative bus.

Mr. J. E. Garrett.* To get back to the question of electrolysis, did I understand Mr. Phillips to say that in Akron the water pipes system was bonded to one of these substations, to the substation that was located centrally in Akron?

Mr. Phillips. Yes.

Mr. Garrett. And has that bond been continued?

Mr. Phillips. So far as I know it is still there.

Mr. Garrett. The pipe being lead or cast-iron pipe?

Mr. Phillips. Yes.

President Barbour. I would suggest to Mr. Liesen, if he is going to write a paper on steel pipe, that one of the great necessities of the present time is to so control the heating preliminary to dipping as to obtain a

* Civil Engineer, Hartford, Conn.

uniform temperature. As I have already stated, the reason that tar was given up on the Akron line was due to failure to obtain such uniform heating. Through the coöperation of Mr. Church of the Barrett Company, one of the best tar chemists in this country, it was proved that the temperature in the pipes, as made for Akron, varied from, say, 250° F. on one side to perhaps 500° F. on the other side of the same pipe, and a coating under these conditions might be soft on one side of the pipe and brittle on the other.

Recently, in connection with the work of the Committee on Standard Specifications for Cast-Iron Pipe, I have had some correspondence with Mr. Church in regard to a specification which would guarantee the use of a straight run coal tar, and his position is practically this, that until we are able to better control the temperature of the cast-iron pipe at the time of dipping it is useless to spend much time in the refinement of the specifications for tar.

Mr. G. F. Sever. Mr. President, I do not have the honor of belonging to your Association, but I have been requested by Professor O. C. Jackson, who was invited to discuss this paper, to attend this meeting. I am an electrical engineer, and it is very interesting to me to see that electricity does not appear to be the scapegoat that it sometimes has been made in water works investigations.

Water Works Engineers have recommended that the electric railroads, on account of the alleged electrolytic damage caused by the current, be compelled to put up double overhead trolley lines and remove their currents entirely from the rails. I am very glad to see now that there are recognized other means causing the destruction of steel and cast iron pipes than our electric railway currents.

I have investigated the corrosion of pipes in Richmond, Va., Dayton, O., Peoria, Ill., and in the vicinity of Philadelphia, in Trenton and other places. I have found water and gas pipes and also Edison tubes which have been treated, lying in certain kinds of soil, particularly with a cinder content, which have been entirely corroded through and destroyed purely from the chemical actions that occurred. And I have had occasion to investigate in the outskirts of Philadelphia an iron gas pipe which was treated at the gas works by a covering of tar and paper,—three layers of paper, each one dipped in a tar compound—and laid in a marshy soil, far removed from the electric railroad. The gas company claimed that the electric railway current was the cause of the continuous destruction of this iron gas pipe. Tests on the electric railroad in that vicinity showed no possibility of any current flow on this gas main, and by applying electrical instruments to the gas main there was found no electric railway current, but the gas main would last possibly two or three months and have to be continually replaced by other and new pipe. Moisture seemed to permeate the covering and localize chemical action on the pipe.

Recently I have had occasion to investigate a large water conduit in the State of Maine. It was of cast-iron and fed a large city. We were called in to make tests on it, to see if there was any possibility of electrolysis caused by the current from a suburban electric railroad. The pipe in this case I believe has been laid 16 or 18 years, and in uncovering it near the railroad we found the asphalt covering absolutely intact. The pipe was lying in a moist soil and we had to scrape the covering from the pipe in order to attach to it by solder a couple of leads for an electrical recording instrument. We observed the pipe at this location through its full length, and all about it, and could not see any deterioration of the protective covering.

In regard to the remarks of the author of the second paper about the action of the electric railroad in analyzing and making an economic study of their electric supply system, I would say that I have had occasion to lay out a number of return feeder systems for electric railroads, and have recommended the absolute taking away of any connection between water supply systems and the negative bus of the railroad, have introduced many negative feeders in order to relieve the rails and pipes of their high electric potentials and have recommended over and over again automatic substations at short intervals in order to reduce the potentials that normally obtain on suburban and interurban railroad systems where the substations are now possibly three to six miles apart, with the ordinary 600 volt direct current system.

So that in almost all cases where there has been any trouble — at least, in recent years — the railroads are endeavoring to remedy the troubles, to mitigate them, and, if possible keep the water supply systems as far away from the railway system and the return feeders as is possible.

PROPOSED EXTENSION OF THE METROPOLITAN WATER DISTRICT.

BY X. H. GOODNOUGH.*

(February 14, 1922.)

Under the provisions of Chapter 49 of the Resolves of the year 1919, the State Department of Health and the Metropolitan Water and Sewerage Board, which is now the Metropolitan District Commission, were directed to consider the water supply needs and resources of the State with special reference to the requirements of certain districts, most important among which is the Metropolitan Water District, created by Chapter 488 of the Acts of the Year 1895.

The first questions to be determined were the present needs of the district and its probable future requirements, and these questions have involved a study of past growth in population and in the use of water. The problem of the population of this district 25 or 50 years hence is of course an insolvable one, and the only safe ground of estimate is to assume that its future growth will continue about as past experience indicates. The original report of the State Board of Health in 1895 recommended a district of 28 cities and towns which contained, in 1890, a population of 848 012 inhabitants. The State Board of Health stated in that report however, that "inasmuch as the cities of Cambridge, Lynn, Newton, Waltham and Woburn and the towns of Brookline, Lexington, Nahant, Saugus, Swampscott and Winchester, together containing, in 1890, 210 252 inhabitants, believe that they have a sufficient supply for some years to come, we do not recommend that they be provided with water from the Metropolitan supply until they formally express their wish for it." The exclusion of these places left 17 municipalities which, it was recommended by the State Board of Health, should constitute the original district, but when the legislation was finally enacted only 13 municipalities were included and that number has since been reduced by the annexation of the town of Hyde Park to the city of Boston. But since the district was formed in 1895 it has been enlarged by the addition of the city of Quincy and the towns of Arlington, Lexington, Milton, Nahant, Stoneham and Swampscott, so that it contains at the present time 19 cities and towns which had in 1895 a population of 763 417. At the end of 1920 the population of this group of municipalities was 1 252 903. The total quantity of water consumed in this district in 1895 was about 69 000 000 gal. per day, and the quantity used in 1920 was 131 000 000 gal. per day, or nearly double the amount used 25 years earlier.

*Director and Chief Engineer, Mass. State Dept. Public Health.

Estimated Population to be Supplied.

A study of the census records shows that the population of the Metropolitan Water District has doubled in the past 32 years. The percentage of growth of the district has been a very steady one. Taking the progressive 30-year increases, it is found that in 30-year periods beginning with the period 1850–1880 and including the period 1885–1915, the increase has ranged from 103.5 to 123.3 per cent; that is, in each of these periods the population has more than doubled in 30 years. In the period which included the recent war, however, there was a decided reduction in the rate of growth, the increase falling from 115.9 per cent in the period 1885-1915 to 89.1 per cent in the period 1890–1920. Of course this falling off was largely if not wholly due to the war, but in estimating the future percentage of growth it has been assumed that this percentage will continue to be a declining one, approximately as shown in the following table.

Table showing Percentage of Population Increase by Thirty-Year Periods, with Estimates for 1920 to 1970.

METROPOLITAN DISTRICT, INCLUDING NEWTON.

Period.	Per Cent Increase.	Period	Per Cent Increase.
1850–1880	123.6	1895–1925	81.2
1855–1885	103.6	1900–1930	73.0
1860–1890	109.6	1905–1935	73.6
1865–1895	123.3	1910–1940	66.8
1870–1900	124.2	1915–1945	59.8
1875–1905	103.5	1920–1950	63.8
1880–1910	113.7	1925–1955	58.0
1885–1915	115.9	1930–1960	52.9
1890–1920	89.1	1935–1965	48.8
		1940–1970	45.1

Using this lesser rate of increase, the future population of the district would be about as shown on the accompanying diagram. On this diagram (No. 1) are shown the actual growth in population from 1870 to 1920 and the estimated growth to 1970. The diagram also shows the future population of the cities and towns now comprising the Metropolitan Water District as estimated in the report of 1895, those estimates having been based on the growth of population up to 1890. The diagram shows that the actual increase in population varied but little from the estimates during the first years — 1890 to 1900 — but from 1900 to 1905 there was a falling off, and then from 1905 to 1915 the lines are nearly parallel. Up to 1915 the estimate of population made by the State Board of Health based on the censuses previous to 1890 exceeded the actual by about 10.9 per cent. Of course in the war period from 1915 to 1920 there was a decided decrease in the growth of the district as in New York and other places, but even in 1920 the difference between the actual and estimated growth based on censuses of 30 years earlier was less than 20 per cent.

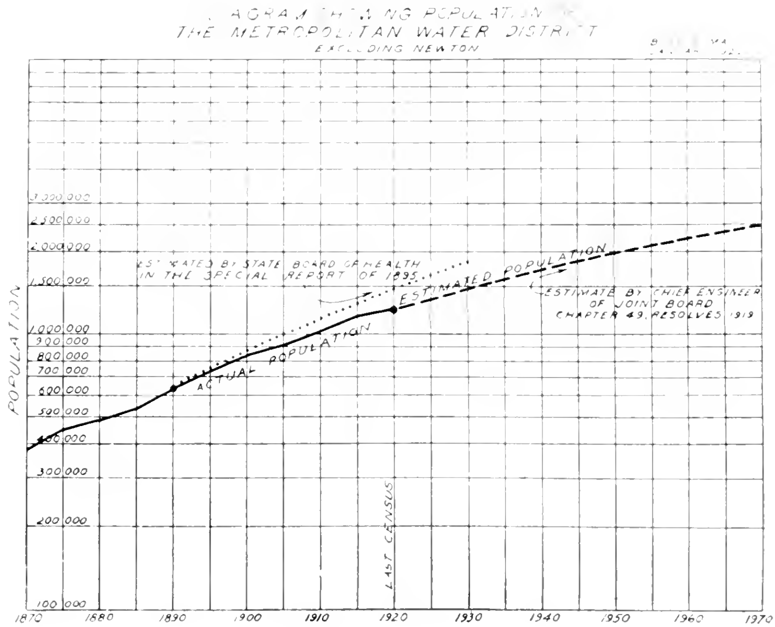


DIAGRAM No. 1.

The growth of the different parts of the district also shows considerable variation as indicated on diagram No. 2. The area of the city of Boston is only some 40 odd square miles, and the rate of growth is lessening as the density of population becomes greater. The portion of the district exclusive of the city of Boston is growing more rapidly than the city itself and there is still a large population outside the district which is showing a steady and rapid growth.

On diagram No. 3 is shown a comparison between the growth of the Metropolitan Water District and of the city of Boston, as compiled by the U. S. Census Bureau, and that of the other great metropolitan centers, of which there are now five in the United States that have a population in excess of one million inhabitants. A study of this diagram shows in the first place that the growth of the city of Chicago was much the most rapid of all for many years but that this rate has in later years diminished and in recent years has been but a little, if any, greater than that of the two cities next in size — Philadelphia and Boston. Compared with Philadelphia, the Boston district grew more rapidly on the whole up to 1915, but its rate of growth was curtailed during the period of the war. The city of Pittsburgh, next to Chicago, has grown at a very rapid rate, but since 1910 its rate of growth has been somewhat less than that of Boston or Philadelphia. The city of New York has grown in recent years more rapidly than the others, though, like Boston, the rate was seriously diminished in the last census period on account of the war. Leaving out the war period, which affected the dif-

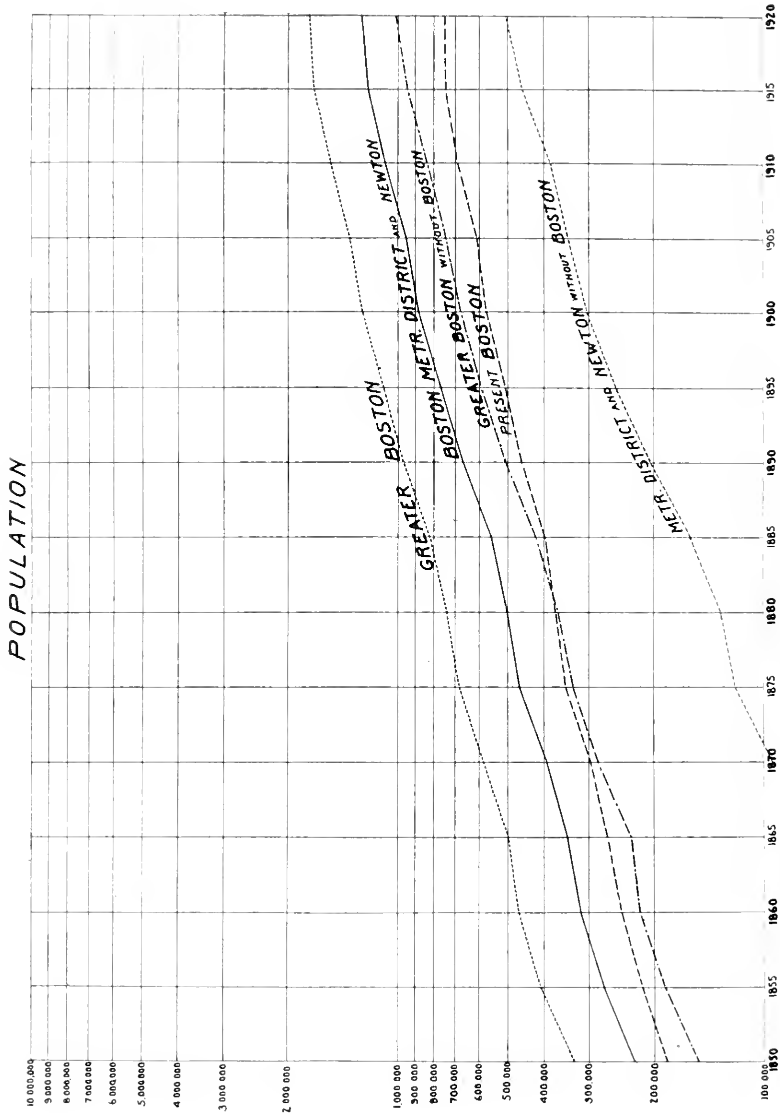

POPULATION
BOSTON
GREATER BOSTON
METR. DISTRICT AND NEWTON
GREATER BOSTON METR. DISTRICT AND NEWTON
BOSTON METR. DISTRICT AND NEWTON
BOSTON WITHOUT BOSTON
GREATER BOSTON WITHOUT BOSTON
PRESENT BOSTON
METR. DISTRICT AND NEWTON WITHOUT BOSTON
10 000,000
9 000 000
8 000,000
7 000 000
6 000 000
5,000 000
4 000 000
3 000 000
2 000 000
1,000 000
900 000
800 000
700 000
600 000
500 000
400 000
300,000
200 000
100 000
1850
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920

Diagram No. 2.

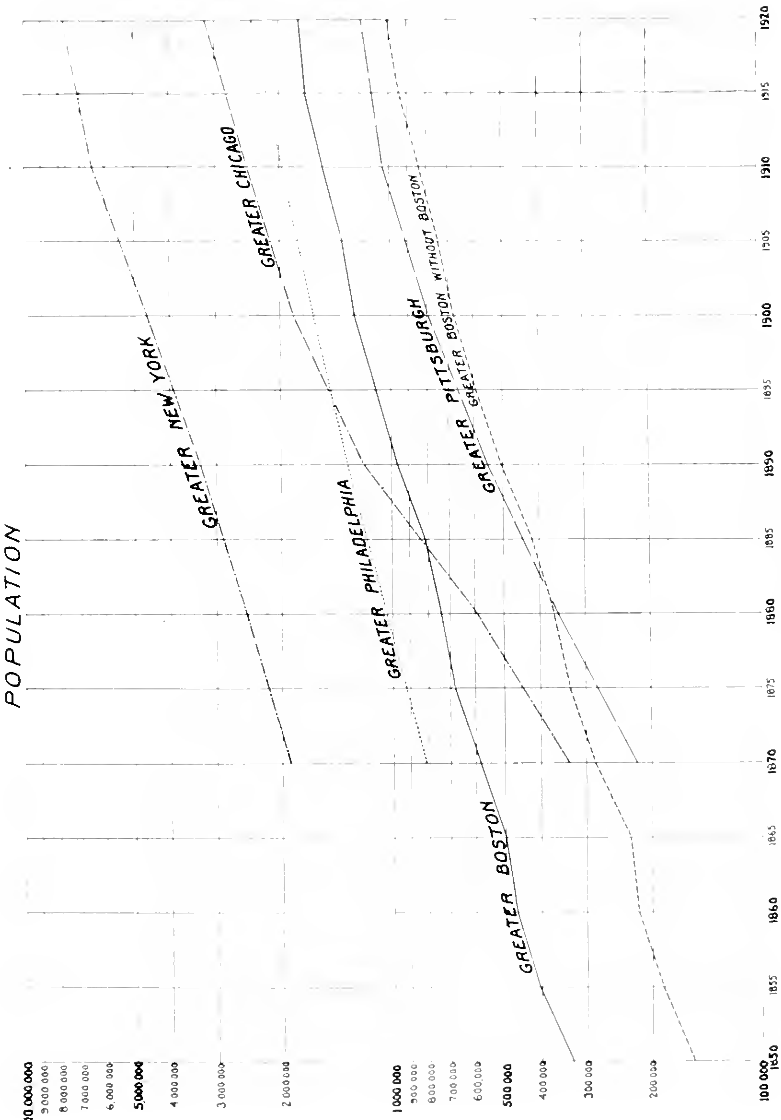

POPULATION
GREATER NEW YORK
GREATER CHICAGO
GREATER PHILADELPHIA
GREATER PITTSBURGH
GREATER BOSTON WITHOUT BOSTON
GREATER BOSTON
10 000 000
9 000 000
8 000 000
7 000 000
6 000 000
5 000 000
4 000 000
3 000 000
2 000 000
1 000 000
900 000
800 000
700 000
600 000
500 000
400 000
300 000
200 000
100 000
1850
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920

Diagram No. 3.

ferent cities in different ways, there is nothing in this record to indicate that the growth of the metropolitan district of Boston is not keeping pace with that of the other great metropolitan centers. Obviously prudence requires that allowance must be made for a rate of growth in the future which shall follow the general curve indicated by the experience of previous years.

Water Consumption in the Metropolitan Water District.

The quantity of water used in the Metropolitan Water District, exclusive of the city of Newton, in 1920 was 127 265 000 gal. per day, or 105.5 gal. to each inhabitant. Including the city of Newton, the total consumption was 130 952 000 gal. per day, or 104.5 gal. per person per day, but the City of Newton provided its entire water supply during the year from its own sources. The aggregate amount of water used in the municipalities which now compose the Metropolitan Water District, excluding the city of Newton, in 1894, the year before the district was established, was 63 759 000 gal. per day, or 89 gal. per inhabitant; that is, the consumption of water in the district, exclusive of Newton, doubled in the 26 years from 1894 to 1920. The consumption of water in the District and in the City of Newton in each year from 1893 to 1920 is shown in the following table:

Average Daily Water Consumption, Metropolitan Water District.

Year.	Metropolitan Water District.	Newton.	Total.
1893	64 795 000	1 370 000	66 165 000
1894	63 759 000	1 623 000	65 382 000
1895	67 698 000	1 801 000	69 499 000
1896	76 548 000	1 812 000	78 360 000
1897	78 989 000	1 804 000	80 793 000
1898	81 893 000	1 758 000	83 651 000
1899	90 075 000	2 036 000	92 111 000
1900	95 973 000	2 086 000	98 059 000
1901	102 802 000	1 843 000	104 645 000
1902	108 418 000	1 927 000	110 345 000
1903	108 168 000	2 109 000	110 277 000
1904	114 937 000	2 188 000	117 125 000
1905	117 757 000	2 151 000	119 908 000
1906	118 567 000	2 223 000	120 790 000
1907	125 307 000	2 318 000	127 625 000
1908	126 479 000	2 444 000	128 923 000
1909	120 240 000	2 344 000	122 584 000
1910	113 239 000	2 505 000	115 744 000
1911	110 907 000	2 583 000	113 490 000
1912	116 231 000	2 732 000	118 963 000
1913	103 848 000	2 889 000	106 737 000
1914	107 036 000	2 960 000	109 996 000
1915	101 942 000	2 830 000	104 772 000
1916	106 338 000	3 099 000	109 437 000
1917	110 032 000	3 121 000	113 153 000
1918	129 764 000	3 426 000	133 190 000
1919	120 594 000	3 488 000	124 082 000
1920	127 265 000	3 687 000	130 952 000

Records from 1893–1903, inclusive, based on pumpage records.
Records from 1904 to date, inclusive, based on meter records.
Records from 1893–1908, inclusive, include small amount of water supplied by Revere to Saugus (this amount not included after 1908).

After the establishment of the district the consumption of water per inhabitant rose very rapidly until 1904, when it reached 128 gal. per capita at a time when the number of metered services in the district was about 11 per cent of the total. Following 1904 the more liberal use of meters was begun in the cities and towns in the district outside the city of Boston, and whereas in 1904 only 19 per cent of the services were metered in these municipalities, by 1908 the per cent of metered services had risen to 47.6 and the number continued to rise to 85.7 per cent in 1915 and 91.1 per cent in 1920. In the city of Boston 6.5 per cent of the services were metered in 1908, 53.1 per cent in 1915 and 62.5 per cent in 1920. In the district as a whole, excluding Newton, the percentage of metered services rose from 10.8 per cent in 1904 to 21.8 per cent in 1908, to 66.6 per cent in 1915 and 74.6 per cent in 1920. It will be seen that, following the legislation in 1907 requiring the general application of meters on all services, the introduction of meters rapidly followed and the consumption per capita in the district as a whole fell from 130.4 gal. in 1907 to 88 gal. in 1915, the latter amount being slightly less than the quantity used in the same municipalities in 1894. This great and rapid reduction in the use of water per capita by means of the general application of meters appeared to solve the problem of waste prevention, a subject which has engaged the serious attention of water works authorities since water works were first introduced; but following the small quantity of water used in 1915 — 88 gal. per capita — which was unquestionably due to a combination of causes all operating to produce a minimum use of water, the consumption of water per capita again began to rise and amounted in 1920 to 105.5 gal. per day. In one of these years, 1918, the amount of water used per capita rose to 109.3 gal. per day in consequence of an unusually cold winter. These changes are shown in the following table and on diagram No. 4.

In the city of Boston the percentage of metered services is less than in the district as a whole, amounting in 1920 to 62.5 per cent while in the district outside of Boston the percentage of metered services in 1920 was 91.1 per cent, but the experience has been practically the same in all of the municipalities composing the district, viz., a great rise in the consumption of water per capita following the creation of the district and a great reduction during the period of the introduction of meters, which continued until 1915 when 66.6 per cent of the services had been metered. After that year the consumption of water again began to rise and has continued to rise though the percentage of metered services has increased from 66.6 to 74.6 per cent.

In view of this marked increase in the consumption of water in the last few years, notwithstanding the general use of meters in the district, it has been deemed important to collect information as to the conditions existing in other cities where the meter system has been in use for any considerable length of time. In connection with this question, information has been obtained from all of the large northern cities of the United States

TABLE SHOWING POPULATION, PER CENT OF METERED SERVICES AND PER CAPITA DAILY CONSUMPTION IN GALLONS IN BOSTON AND THE METROPOLITAN WATER DISTRICT.

	Metropolitan Water District						Boston.			Metropolitan District Minus Boston.					
	Including Newton.			*Excluding Newton*						*Including Newton.*			*Excluding Newton.*		
Year	Population.	Per Cent. Met'r'd	Per Capita Con.	Population.	Per Cent Met'r'd	Per Capita Cons.	Population.	Per Cent Met'r'd	Per Cap. Cons.	Population.	Per Cent Met'r'd	Per Cap Cons.	Population.	Per Cent Met'r'd.	Per Cap. Cons.
1904	936 861	14.4	125.0	900 682	10.8	127.6	602 739	5.9	147.2	334 122	27.0	85.1	297 943	19.0	88.1
1905	951 641	16.0	126.2	914 814	12.5	128.8	609 890	6.1	149.0	341 751	30.5	85.0	304 924	23.0	88.2
1906	975 434	18.5	123.9	938 011	15.1	126.5	625 130	6.3	147.2	350 304	36.2	82.2	312 881	29.5	84.9
1907	999 237	21.0	127.7	961 218	17.7	130.4	640 371	6.4	152.4	358 866	42.1	83.7	320 847	36.2	86.4
1908	1 023 010	24.9	126.0	984 396	21.8	128.4	655 611	6.5	151.6	367 399	52.4	80.3	328 785	47.6	82.3
*1909	1 046 493	31.4	117.1	1 007 283	28.6	119.3	670 852	12.9	141.8	375 641	57.3	73.1	336 431	53.4	74.5
1910	1 070 256	40.0	108.2	1 030 450	37.5	109.9	686 092	20.7	129.0	384 164	66.7	71.0	344 358	63.8	71.9
1911	1 096 466	47.7	103.5	1 055 999	45.5	105.0	697 962	28.1	123.9	398 504	74.4	67.8	358 037	72.3	68.2
1912	1 122 675	53.7	106.0	1 081 546	51.7	107.5	709 831	34.8	126.8	412 844	79.1	70.4	371 715	77.5	70.5
1913	1 148 881	59.2	92.8	1 107 091	57.6	93.9	721 700	41.4	110.0	427 181	82.7	64.1	385 391	81.7	63.5
1914	1 175 091	63.9	93.6	1 132 639	62.5	94.6	733 570	47.4	111.6	441 521	85.2	63.7	399 069	84.5	63.0
1915	1 201 300	67.8	87.2	1 158 187	66.6	88.0	745 439	53.1	104.2	455 861	86.3	59.5	412 748	85.7	58.8
1916	1 211 618	71.8	90.4	1 167 917	70.8	91.1	745 936	58.3	107.7	465 682	88.6	62.4	421 981	87.9	61.6
1917	1 221 941	73.3	92.6	1 177 652	72.2	93.5	746 433	59.9	110.0	475 508	89.8	65.4	431 219	89.0	64.9
1918	1 232 261	73.6	108.1	1 187 383	72.4	109.3	746 929	59.9	126.7	485 332	90.3	79.5	440 454	89.5	79.8
1919	1 242 586	74.4	99.8	1 197 120	73.3	100.7	747 426	60.5	119.9	495 160	91.1	69.5	449 694	90.4	68.8
1920	1 252 903	75.6	101.5	1 206 849	74.6	105.5	748 060	62.5	126.0	504 843	91.3	72.6	458 789	91.1	71.9

* Prior to 1909 the water consumption of Revere includes that of a small part of Saugus and consequently prior to that year the estimated population of the part of Saugus supplied has been added. This amounts to only 200-280 persons.

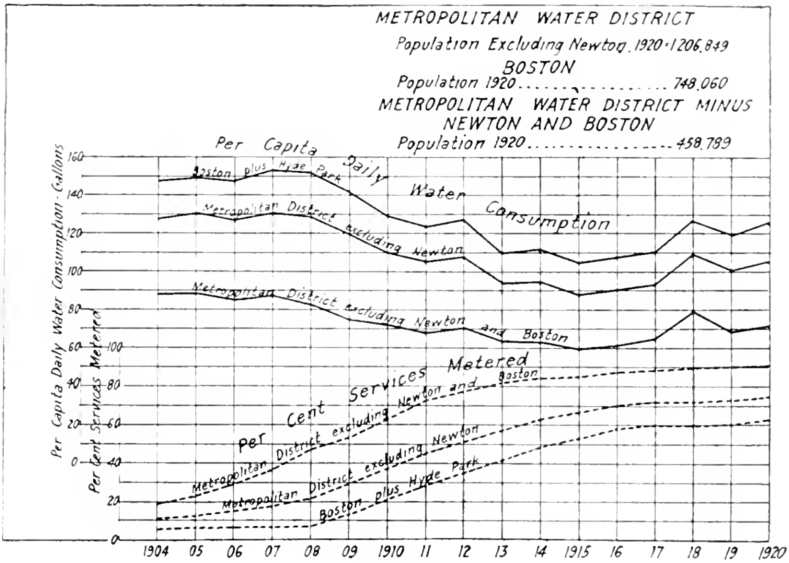


DIAGRAM NO. 4.

east of the Rocky Mountains where climatic conditions are similar to those at Boston. In this territory there are 13 cities, exclusive of the Boston Metropolitan District, having by the census of 1920 a population in excess of 400 000. The records of the consumption of water per capita in each of these cities, together with the percentage of services metered, has been furnished by city officials, the information covering in most cases periods as long as 30 years. From these records it appears that in 5 of these cities over 90 per cent of the services are metered, while in all of the other cities, the percentage of metered services is less than in the Metropolitan Water District; these 5 cities and the percentage of services metered in each in 1920 are shown in the following table;

Detroit	97 per cent.
Cleveland ...	100 per cent.
Milwaukee ..	99 per cent.
Cincinnati ...	99 per cent.
Newark ...	92 per cent.

In this list of cities the application of meters to services generally has been so recent in two of the cities — Detroit and Cincinnati — that little information is furnished by their experience as to the changes in the consumption of water after two-thirds to three-fourths of the services have been metered.

The accompanying diagrams Nos. 5 and 6 show the per capita consumption and the per cent of metered services in these 5 cities, so far as the records of consumption are available.

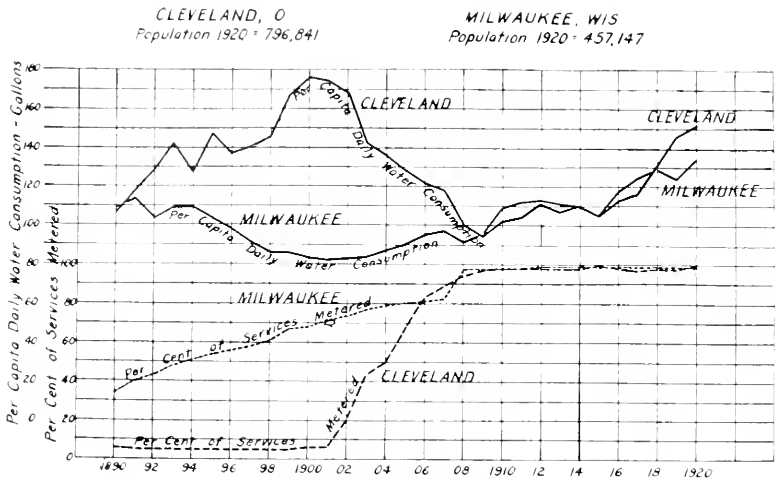


DIAGRAM No. 5.

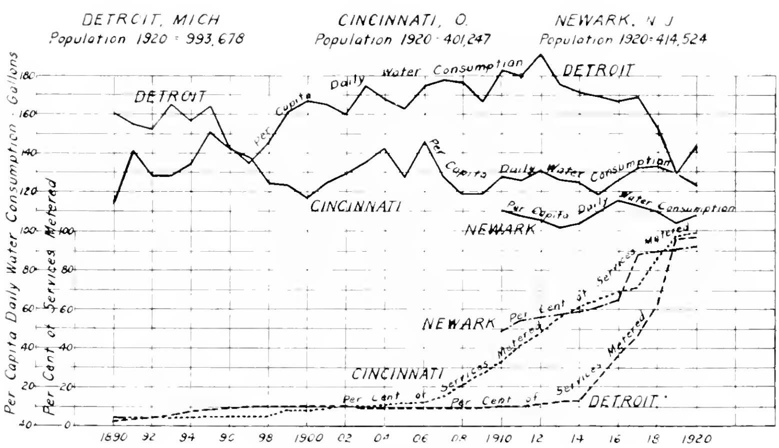


DIAGRAM No. 6.

In Cleveland the general introduction of meters was begun about 1900 when less than 10 per cent of the services had been metered and the consumption per capita was 176 gal. The amount of water used per capita decreased rapidly as the number of meters increased until in 1905, when 68 per cent of the services had been metered, the consumption per capita had fallen to 128 gal. It continued to fall for 4 years more until in 1909 when it amounted to 94 gal. with 97 per cent of the services metered. Since 1909 with over 97 per cent of the services metered the consumption of water per capita has again risen and amounted to 152 gal. in 1920.

In Milwaukee the experience has been similar to that of Cleveland. A high per capita consumption of water was reduced by the general intro-

duction of meters, and when 72 per cent of the services had been metered in the year 1901 the consumption of water per capita had fallen in the previous 10 years from a maximum of 113 gal. to a minimum of 82 gal. Between 1901 and 1909 practically all of the remaining services were metered and all services have been metered during the last 11 years. Since 1901, however, the consumption per capita in this completely metered city has risen from 82 to 134 gal. Variations in the consumption of water per capita and the percentage of metered services in Cleveland and Milwaukee are shown on diagram No. 5.

In Newark, in the years 1912, 1913 and 1914, when at least 56 per cent of the services were metered, the average consumption was 104 gal. per day. In 1918, 1919, and 1920, when the percentage of metered services had increased to from 90 to 92 per cent, the per capita consumption averaged about 107 gal. per day. While the period has been too short a one to form satisfactory conclusions, so far as the records show up to the present time the increase in the percentage of metered services from less than 60 to over 90 has been accompanied by an increase in the consumption of water per capita.

Information has also been collected from cities having less than 400 000 inhabitants in 1920, in which a large percentage of the services are metered. The number of such cities from which records have been obtained which have a population in excess of 25 000, including 9 in Massachusetts, is 19; and in addition there are 3 other cities in which from 75 to 85 per cent of the services were metered in 1919 or 1920. The per capita consumption and the percentage of services metered in practically all of these cities are shown in diagrams Nos. 7, 8, 9, 10, 11, 12.

Diagram No. 13 shows the consumption of water per capita and the per cent of metered services in a residential district comprising Brookline, Newton, Needham and Wellesley, containing in 1920 a population of 97 038, — these municipalities being adjacent to the Metropolitan Water District and one of them, the city of Newton, a member of the district, though that city does not take water from the district sources at the present time.

The experience in the various cities following the general metering of the services as presented in the diagrams shows that in a great majority of cases the general introduction of meters in a city in which few meters have previously been in use has been followed by a large reduction in the use of water per capita. The experience in the Metropolitan Water District in this respect is duplicated in practically all of the cities for which records have been obtained. But the diagrams also indicate clearly that in the great majority of these cases after two-thirds or more of the services had been metered the consumption of water per capita sooner or later began again to increase and has continued to increase up to the present time, notwithstanding the continued application of meters until most or all of the services have been metered.

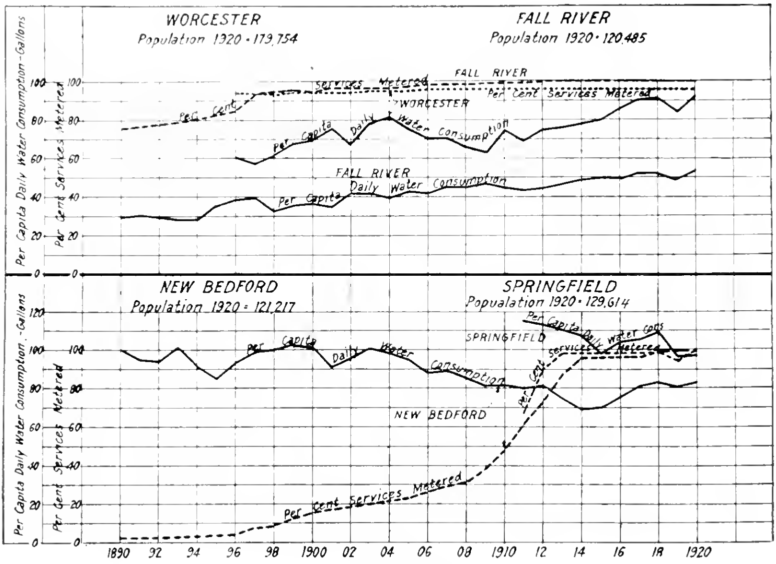


Diagram No. 7.

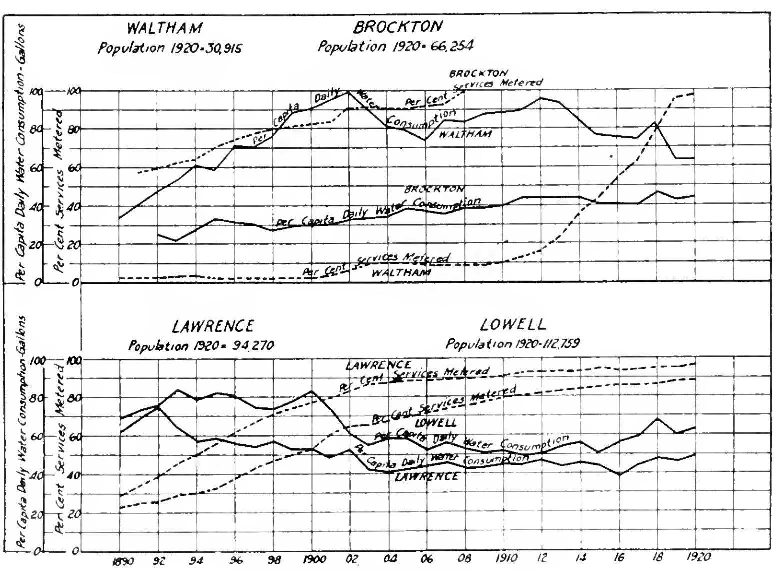


Diagram No. 8.

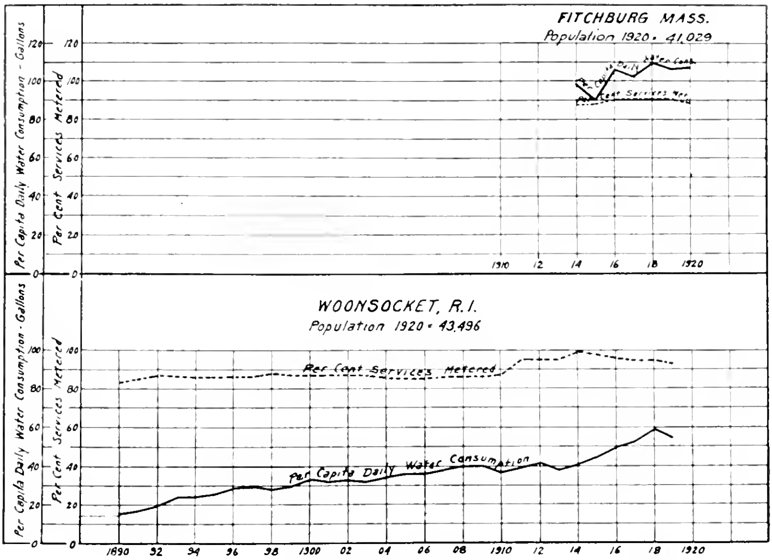


Diagram No. 9.

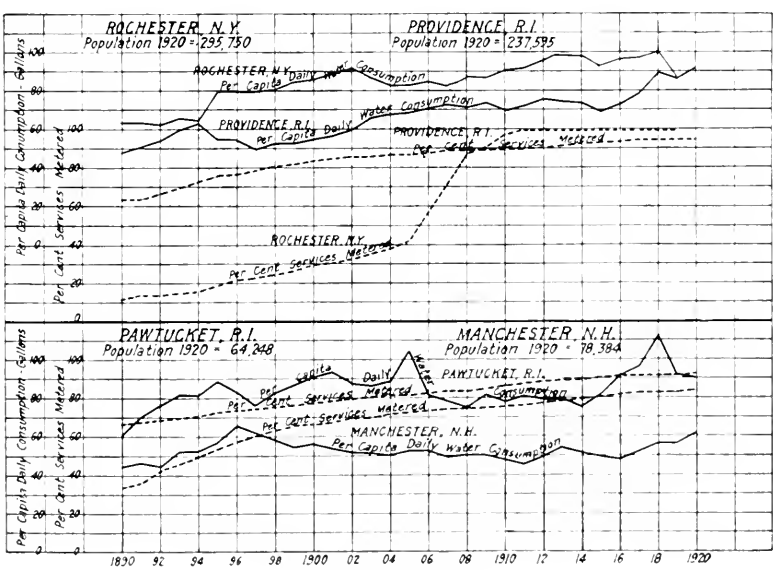


Diagram No. 10.

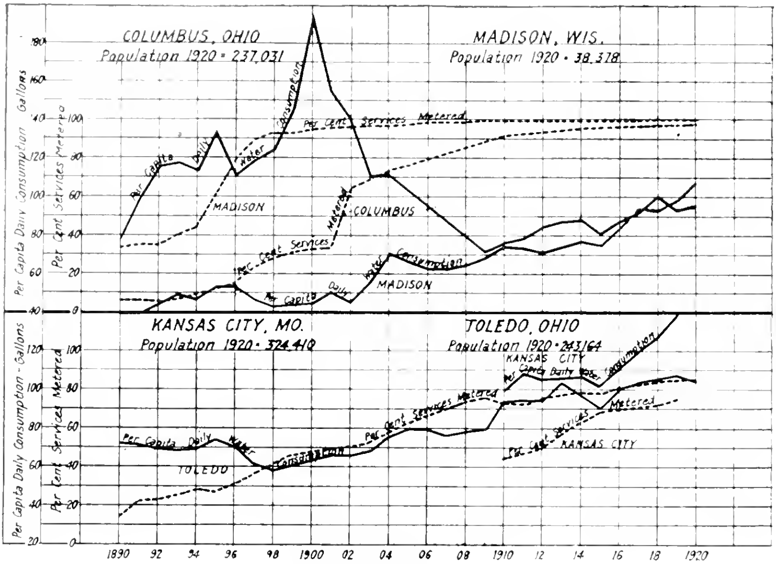


DIAGRAM No. 11.

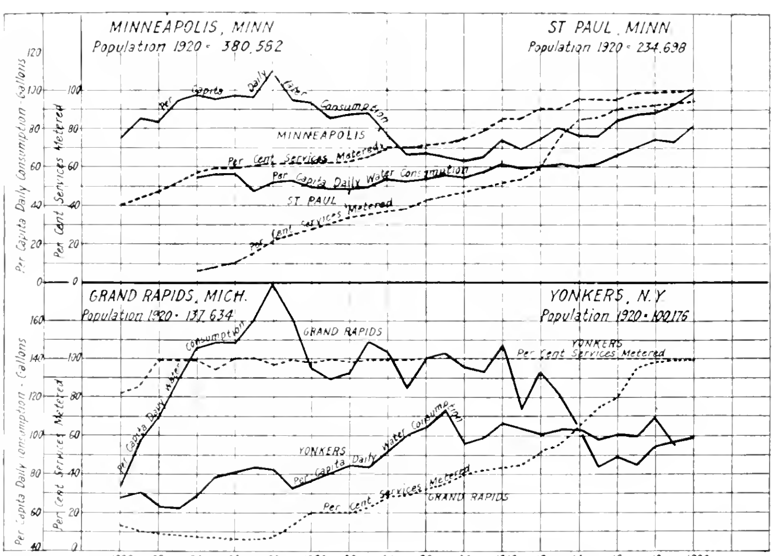


DIAGRAM No. 12.

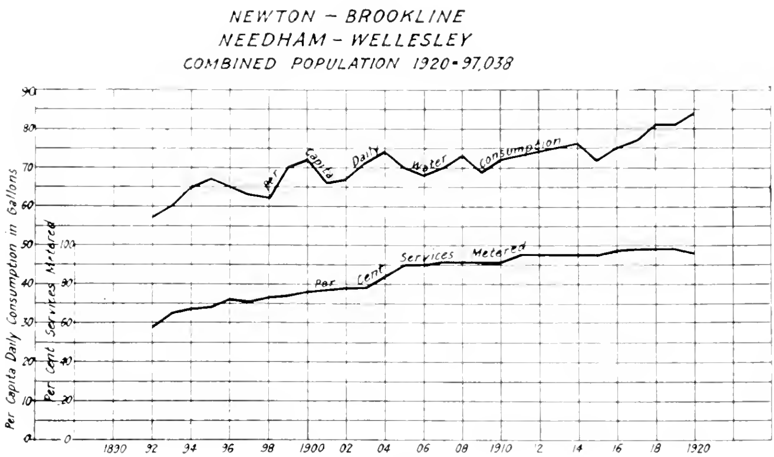


DIAGRAM NO. 13.

GENERAL INCREASE IN THE CONSUMPTION OF WATER PER CAPITA AFTER TWO-THIRDS TO THREE-FOURTHS OF THE SERVICES HAVE BEEN METERED.

In this study the object has been to learn what changes have taken place in the consumption of water per capita after two-thirds to three-fourths of the services have been metered, as is the case in the Metropolitan Water District. The table on page 204 shows the changes in the use of water per capita in the cities for which records have been obtained in which the percentage of metered services in 1920 is substantially greater than 75 per cent and in which a sufficient number of years has elapsed after a substantial per cent of the services were metered to furnish information as to the changes in the per capita consumption with the increased use of meters. In this table an average of 3 years, when about 74 per cent of the services had been metered in each city, is compared with an average of the last 3 years available, usually the years 1918, 1919 and 1920.

From this table it appears that in all but 2 cases — those of Hartford and Lawrence—there has been an increase in the consumption of water per capita since 75 per cent of the services were metered; the average increase when comparison is made of the years 1918, 1919 and 1920 being 1.42 gal.; or, using the years 1917, 1918 and 1919, 1.31 gal. In Hartford the full effect of metering does not appear to have been secured when the number of meters was increased from 6 to 71 per cent in 3 years. For some time after this sudden increase in the use of meters the use of water per capita decreased, but in the last 13 years there has been an increase of 0.38 of a gallon per capita per year. In Lawrence the consumption of water per capita since 1900, when more than 75 per cent of the services were metered, has decreased 0.2 of a gallon per person per year; but since becoming more

City	Years since about 75% Services became Metered.	Increase or Decrease in Consumption of Water per Capita in those Years (Gals. per Year).
Cleveland	13	1.59
Milwaukee	17	2.70
Minneapolis	11	2.61
Rochester	11	1.48
Providence	24	1.33
Toledo	11	2.52
St. Paul	6	2.61
Hartford	18	−0.50
Yonkers	29	1.15
Pawtucket	22	0.79
Manchester	11	0.73
Atlantic City	20	3.73
Madison	23	2.12
Burlington	17	1.10
Woonsocket	28	1.42
Worcester	23	1.26
Fall River	29	0.80
Lawrence	20	−0.32
Lowell	12	0.86
New Bedford	7	0.57
Brockton	23	0.57
Fitchburg	5	2.07
Average		1.42*

Yonkers, N. Y. — Records begin 1890 with 82% metered services.
Woonsocket, R. I.— Records begin 1890 with 83% metered services.
Fitchburg, Mass. — Records begin 1914 with 87% metered services.
Worcester, Mass. — Records begin 1896 with 93% metered services.

than 90 per cent metered in 1910 the consumption of water has increased at the rate of 0.4 of a gallon per person per year. In Fall River after the percentage of metered services reached about 75 the increase in the consumption of water per capita in 30 years was 0.8 of a gallon per person per year. After meters had been applied to more than 90 per cent of the services the increase has been 0.61 of a gallon per year. Of all this group of cities the important ones which show a decrease in the consumption of water per capita are Newark, Lawrence and Hartford and, as already seen, even in these cases apparently after the full effect of metering had been experienced the consumption of water again increased.

In the more fully metered communities in the Metropolitan Water District outside of Boston there has also been an increase in the consumption of water per capita in the last 6 years. In the suburban municipalities of Brookline, Newton, Needham and Wellesley the increase since 70 per cent of the services became metered in 1896 has been about 0.8 of a gallon per person per year. But while as a general rule no further material reduction in the use of water per capita is effected by the complete metering of all the

* This average would be 1.31 if average of returns for 1917, 1918 and 1919 is used.

services after about two-thirds to three-fourths of the services have been metered, nevertheless there has been in many cases some further reduction in the use of water per capita afterwards; or at least a temporary reduction has been effected which has retarded for a few years the increase in the consumption of water per capita in fully metered cities. In some of these cases where the meter system was adopted many years ago information is lacking as to the effect of metering the remaining services after a total of 75 per cent had been reached; and in others the complete metering of the services was carried out too recently to furnish definite information with respect to this question; while in still others the application of additional meters after a total of two-thirds to three-fourths of the services had been metered was accompanied by a steady increase in the consumption of water per capita. However, in the 11 cities for which records are available, the application of meters to the remaining services, after two-thirds to three-fourths of the services had been metered, caused for a time a reduction in the consumption of water per capita. In these cities the amount of the reduction ranged from 1 to 18 gallons per capita and averaged 9 gallons, in periods ranging from 1 to 14 years and averaging 4½ years. After this period the consumption of water per capita again began to increase and returned to its earlier figure in from 2 to 12 years, except in the case of one small manufacturing city where the period amounted to 21 years. The length of this period of return averaged 8.6 years; or, if the city referred to were excluded, 7.4 years. It is to be noted that the reduction in the consumption of water per capita as shown in these cases usually followed a much greater previous reduction due to the application of meters up to two-thirds or three-fourths of the total number of services and was a continuation of that reduction. There is no case in which the consumption of water has later been reduced, after it had begun to increase, when two thirds to three-fourths of all the services were metered, as in the case of the Metropolitan Water District.

In general then, so far as these records show, the full effect of metering is reached after a total of about 75 per cent of the services have been metered, but the effect of applying meters to the remaining services in many cases is to effect a further reduction for a time and to delay for a few years the beginning of the increase in the consumption of water per capita after the application of meters has become nearly or quite complete. The practically invariable rule, however, is that after 75 per cent of the services have been metered the consumption of water again increases, and even in fully metered cities continues to increase in spite of the complete adoption of the meter system. This is no argument, of course, for not completing the metering of all services. Aside from the saving in water consumption, metering is the only equitable way in which to assess the charges for water; and without complete metering there will continue to be waste which might be prevented by the use of meters.

The results of this study as a whole show clearly that there has not

only been a decided increase in the use of water per capita after complete metering in great cities like Cleveland, Minneapolis, St. Paul and Providence, but also in small cities in all parts of the United States where climatic conditions are similar to those existing in the Metropolitan Water District.

Inquiry has also been made concerning the experience in English cities as to the changes taking place in the consumption of water per capita and the allowances which are being made therefor, the results of which are shown in the following table.

City	Average Increase in Consumption per Capita (U. S. Gallons per Year).	Number of Years included.
Bradford	0.8	1909–1918
Glasgow	0.4	1909–1920
Leicester	0.6	1908–1920
Manchester	0.5	1907–1920
Nottingham	0.4	1907–1920
London	0.8	1907–1920
Liverpool	0.6	1905–1919

It thus appears that what is true in American cities is also true in English cities, namely, that there is a continued increase in the consumption of water per capita, and in estimating for future requirements English engineers are providing for such an increase.

Causes of the Increase in Water Consumption.

The causes of this general increase in the per capita consumption of water are no doubt due in part to a gradually improving standard of living and to growth in business and industry. The number of water fixtures in dwelling houses has increased enormously in proportion to the population in the last 40 years. Every dwelling place is supposed to have at least one bath tub and many dwelling houses now have two or more.

Even with this increase in use, the domestic consumption in many cities is less than the amount used for manufacturing purposes. In some cases the amounts used for manufacturing are very large. In the city of Peabody, for example, where a special kind of manufacturing using large quantities of water has become established, the consumption of water, notwitstanding the fact that 90 per cent of the services are metered, has constantly risen until in 1920 it exceeded 200 gal. per capita. It has been impracticable to determine the relative quantities of water used for various purposes in the Metropolitan Water District, but the relative amounts drawn for various purposes in an industrial city are indicated by the following records of consumption in the city of New Bedford in 1920, kindly furnished by Mr. S. H. Taylor, Acting Superintendent of the Water Works.

	Cons. Per Capita (Gallons).	Per Cent of Total.
Domestic consumption	28	36
Manufacturing and mechanical uses	41	52
Testing, flushing, fountains and all other purposes, including fires,	9	12
Total	78	100

In residential sections of the Metropolitan Water District the consumption of water per capita is probably larger than in New Bedford, but even then it is probably less than double the quantity used for domestic purposes in that city. In the outlying districts with large lawns and gardens the consumption of water is higher, as shown by the amount used in Brookline, Newton, Needham and Wellesley in the diagram already exhibited. While the amount of manufacturing in these towns is comparatively small, yet with nearly 100 per cent of the services metered they are using over 80 gal. per capita. The use for manufacturing in the Metropolitan Water District is probably less per inhabitant than in the case of New Bedford.

It will be noted that the consumption of water per capita in the city of Boston is much higher then in any other cities and towns of the Metropolitan District and that the percentage of metered services is less than in the district outside the city. The per capita consumption in Boston rose to 152.4 gal. in 1907 before the general use of meters, and dropped to 104.2 gal. in 1915 after about 53 per cent of the services had been metered. Since that time the amount used has increased, amounting to 126 gal. in 1920. It is possible that a considerable reduction may be effected in the consumption of water in the city of Boston by the application of meters to the remaining services, though this seems hardly probable. It is natural that the consumption of water per capita in the city of Boston should be considerably higher than in the Metropolitan District as a whole, because the city contains the principal business center of the entire district and is peopled during the day by many thousands who live in other parts of the district or outside its borders. No doubt a very large quantity of water is consumed in the down-town section of the city by those who live in other places, thus greatly increasing the consumption of water per capita charged to Boston. Some indication of the increase in population of the city of Boston in the day time is furnished by records of passengers carried by the railroads, the subways, elevated and trolley lines, and from these records it is possible to estimate probably quite closely the population which is to be provided for in addition to that of the city itself. From a study of these records it appears probable that the population of the city of Boston is increased during the day time by some 250 000 people or more, who live outside its limits. When the fact is taken into account that the population is increased one-third during the day time, it is important that allowance for this increase be made in estimating the degree to which the consumption of water in the city can be reduced. In view of the fact that the consumption has begun to increase since 62 per cent of the services were metered, there is no great encouragement to expect that a further material reduction in the consumption of water per capita will be effected by metering the remaining services.

Possibility of Reducing the Consumption of Water by the Use of Auxiliary Supplies for Manufacturing.

This question has always arisen in connection with investigations for an additional water supply. The only large sources of supply of fresh water are the rivers which flow through the district, especially the Charles, the Mystic and the Neponset rivers, which carry considerable volumes of water, especially in the winter and spring. A large part of the flow of the Charles River is withdrawn before it reaches the Metropolitan Water District in the drier part of the year, and very little water is available except in the Charles River Basin. The water of the basin might possibly be used for some manufacturing purposes during a considerable part of the year, especially towards its upper end, but during much of the time the water of the basin is largely salt, and this is especially true in dry years. It is not probable that any considerable permanent supply of water for manufacturing can be obtained from that source. The water of the Neponset River and of the Mystic River within the limits of the Metropolitan District are far too badly polluted for most manufacturing purposes. There are large numbers of wells within the limits of the Metropolitan District and in some sections where conditions are favorable for the purpose considerable quantities of ground water are obtained, but the areas in which water can be obtained from the ground in considerable quantities are quite limited and the aggregate amount of water obtainable in this way for manufacturing is probably insignificant as compared with the amount used from the public works. There is little to expect in the way of increased water supply from the further development of local sources for industrial uses.

Prevention of Losses by Leakage.

The prevention of loss of water by leakage from distribution pipes is receiving much attention especially by the Boston Water Department, and excellent results have been obtained during the comparatively short time this work has been in progress, a considerable saving in the loss of water having already been effected. The results of this work so far as it has been carried indicate, however, that the preventable loss of water is not great in comparison with the whole amount of water used and such loss is likely to persist and to be more or less constant even with the most efficient inspection practicable. This is true especially in some of the older parts of the city where the water pipes have been laid for many years in streets in which numerous other structures have been placed, increasing the danger of breaks and leaks. It is probable that most of the loss of water by leakage from water pipes is due to numerous comparatively small leaks which are distributed over so great a length of pipe line that the cost of wholly eliminating them would obviously be prohibitive, but the work of eliminating losses of water by leakage, so far as it is practicable to eliminate them, is of the highest importance in preventing a greater increase in the consump-

tion of water per capita and losses and damage in other ways. While in earlier years, when water mains were sometimes constructed of inferior material or laid without sufficient care, the losses of water by leakage from pipes were in some cases large, it is probable that such installations have been for the most part eliminated and it is doubtful whether there is a material preventable loss of water by leakage from water mains in the Metropolitan Water District as a whole at the present time.

Consumption of Water in the Great Cities of the United States.

It is of interest in considering the probable future use of water in the Metropolitan Water District to compare the consumption per capita with that of other great cities in the United States at the present time. This comparison is shown in the following table, which includes all of the northern cities east of the Rocky Mountains which had a population in 1920 in excess of 400 000. From this table it appears that the consumption of water in the Boston Metropolitan District is less than in any city of over 400 000 inhabitants in the northern part of the United States where the climatic conditions are similar to those at Boston.

Comparison of Consumption of Water per Capita in Metropolitan Water District with Consumption in Northern Cities of the United States where Population is in Excess of 400 000.

	Population.	1920 Per Cap. Cons. (Gallons).	% Metered Services.
New York	5 620 048	131	...
Chicago	2 701 705	253	.
Philadelphia	1 823 779	170	23
Boston Met. Dist.*	1 252 903	104.5	75.6
Detroit	993 678	144	97
Cleveland	796 841	152	100
St. Louis (Mo.)	772 897	135	8
Baltimore	733 826	154	3
Pittsburgh	588 343	236	38
Buffalo	506 775	271	8
Milwaukee	457 147	134	99
Washington	437 571	114	85
Newark	414 524	108	92
Cincinnati	401 247	123	99

* Including Newton.

Variation in the Consumption of Water from Year to Year.

In studying the records of water consumption of the past with a view to applying them in estimating for the future, it is necessary to make allowance for variations due to a variety of causes, among which are the activity of business and industry, meteorological conditions, the efficiency of methods of preventing unnecessary use and waste, besides other circumstances.

Business and industrial conditions have a material effect upon the consumption of water because of its extensive use for mechanical, manufacturing and general industrial purposes. The very low consumption of water between 1893 and 1896 was doubtless largely due to the great business depression in those years. The same is true in 1915 and, while complete returns are not available for 1921, a similar reduction is to be expected in that year. Meteorological conditions — heat, drought, excessive cold or unusual rainfall — also produce very marked variations in the consumption of water from year to year. In very dry periods much more water is used than in years of average rainfall and in periods of great heat the draft upon the water supply system is much larger than usual. Excessive rainfall, on the other hand, if occurring in the warmer part of the year, reduces the draft of water from the public works.

More marked even than great heat or drought is the effect of winter temperatures upon the use of water. In very cold winters the use of water is greatly increased because of the necessary waste to prevent the freezing of pipes. This amounted in a recent cold winter to an average of over 18 million gallons per day during the four winter months.

No doubt a part of the low consumption in 1915, as already stated, was attributable to the poor business conditions in that year, but a large part must also be attributed to the mildness of the winter and to the unusual summer rainfall. In 1921 there was also an extremely mild winter, one of the mildest ever recorded in New England, and a very wet summer. There was also a serious business depression, more severe probably than in 1915, and these conditions should cause a very low consumption of water in 1921.

Another cause of variation in the consumption of water from public works in the past has been that resulting from the varying efficiency of methods adopted for the prevention of waste. In earlier years inspection was relied upon to prevent loss of water in this way, but not until the application of meters to water services generally, furnished a means of preventing unnecessary waste by charging for it at the usual rates, was an adequate method of waste prevention put into effect. That this method has been most effective in preventing excessive use and waste of water is well shown by the decrease in the consumption of water in nearly all cities, including the Metropolitan Water District, following the general introduction of meters. This decrease was no doubt due in part to the fear of large water bills under the meter system, but since experience did not show

that the use of meters caused a materially higher charge to the householder than the former system, provided the plumbing was kept in reasonably satisfactory condition, and since in many cases the charge was less than before the meter was applied, it is probable that after a time less care is exercised in restricting the amount of water used than was the case when the meter was first installed. There are cases also in which after the meter system has been put in operation it has not been maintained with the care and efficiency necessary to the best results and its effectiveness has become materially reduced. These conditions have appeared thus far only in a very few cases, but the fact that they have occurred is an indication that there are likely to be variations in the consumption of water in the future due to the varying efficiency in the maintenance of the meter system and in the efforts made to prevent waste.

The conclusions to be drawn from the experience of the cities in which service pipes are largely or wholly metered shows clearly that, notwithstanding the general use of the meters, there is an increase in the use of water per capita at the present time in practically every city without exception. The continued use of meters can probably be depended upon to prevent such great increases as were experienced before their use was begun and to keep the waste of water within reasonable limits. This increase will vary from causes such as those already indicated, but that it can be wholly prevented in the future by any means which are now available seems improbable.

Summarizing the results of this study, it is found that there has been on the whole a steady increase in the per capita consumption of water ever since a water supply was first introduced into the principal city of the district many years ago. Its causes are:

(1) The introduction of ample supplies of pure, soft water, supplied under ample pressure in any desired part of a dwelling house, store or factory and capable of advantageous use for a great number of purposes.

(2) A gradually improving standard of living accelerated no doubt by the experiences of the war which have led to a demand for better housing, more plumbing fixtures and other aids to comfort and health obtainable through a freer use of water from the public works.

(3) The increasing use of water for manufacturing and mechanical purposes, especially where no large quantities of fresh water are available for such uses except from the public works.

(4) Unpreventable waste from numerous small leaks which could be repaired only at excessive cost and which with ageing pipes and structures will doubtless continue, notwithstanding the fact that a large amount of waste has been and must continue to be eliminated to the fullest practicable extent.

(5) Metering the remaining services after 75 per cent have been metered is unlikely to have any material effect in reducing the consumption of water per capita, while on the contrary the common and well-nigh

universal experience has been that the per capita consumption continues to increase after 75 per cent of the services have been metered, notwithstanding the increase in the number of meters.

(6) The consumption of water per capita in the Metropolitan Water District is not excessive when compared with cities of similar size in this country. On the contrary it is now decidedly less than in any city of similar population and climatic conditions in the United States.

(7) The cost of water is and will continue to be exceedingly small for a very long time to come; in fact the present price for the average family seldom exceeds the cost of the daily newspapers, and the charge for water is not included in the general tax levy. It is a special tax and on account of the fact that some of the water income is diverted in many cities for other municipal uses, the charges for water even now are higher in some places than they need to be if the water revenue was used solely for providing and maintaining a water supply.

(8) Heat, drought, and excessive cold all produce marked variations in the consumption of water and large allowances must be made for variations from such causes. Extremes of temperature and of rainfall such as have occurred in the past will occur again and perhaps in even greater severity.

It is of course impossible to estimate with certainty the quantity of water that will be used per capita in the Metropolitan District in future years; but in the face of the evidence that the use of water has ever been a constantly increasing one and that the indications point to a growing use in the future, it is unreasonable to ignore the available facts, and while every effort must be made to keep the water consumption within reasonable limits, the health of the people should not be placed in jeopardy or the public put even to serious inconvenience because of the assumption that means can and will be found and applied in the immediate future to restrict the growing use of this important necessity. Prudence requires, that — in estimating for the future — allowance shall be made for an increase in the consumption of water per capita to the extent indicated by past experience.

Estimated Increase in Water Supply Requirements in the Metropolitan Water District.

In the cities included in the table already given the increase in the consumption of water per capita in metered cities has ranged as a general rule from 0.85 to 2.50 gal. per person per year and has averaged 1.31 gal. per year if the year 1920 be omitted. If comparison is made of the consumption of water in the cities of Boston, Somerville, Chelsea and Everett in the early 80's, when effective measures were being enforced to prevent unnecessary use and waste of water, with the consumption of water in the same municipalities in 1920, it appears that the consumption has increased at about the same rate.

The record of the use of water in these four cities covering a long period of years is a very interesting one in this connection, and a summary has been made of the available information as to the consumption of water in these cities since a water supply was first introduced into the city of Boston in 1848. The construction of the Mystic works was not begun until 1862, or 14 years after the completion of the Cochituate works designed for the supply of the city of Boston.

The population and consumption of water, so far as the records show, in these four cities is given in the following table:

Population and Water Consumption.

(Boston with annexations, 1849–1872, inc.)

(Boston with annexations with Somerville, Chelsea and Everett, 1873–1920 inc.)

Year.	Population.	Av. Daily Cons. Mil. Gals.	Per Capita Daily Cons. Gals.	Per Cent Services Metered.
1849	132 378	3.6800	27.8	
1850	136 881	5.8379	42.7	
1851	141 603	6.8838	48.6	
1852	146 325	8.1258	55.5	
1853	151 046	8.5423	56.6	
1854	155 768	9.9020	63.6	
1855	160 490	10.3463	64.5	
1856	163 960	12.0486	73.5	
1857	167 430	12.7260	76.0	
1858	170 900	12.8470	75.2	
1859	174 370	13.1750	75.6	
1860	177 840	17.2380	96.9	
1861	180 736	18.1893	100.6	
1862	183 631	16.6000	90.4	
1863	186 527	16.2385	87.0	
1864	189 422	16.6810	88.1	
1865	192 318	12.6620	65.8	
1866	194 557	12.2290	62.8	
1867	227 752	13.5650	59.6	
1868	231 257	14.7692	63.9	
1869	246 713	15.0704	61.2	
1870	250 526	15.0077	59.9	
1871	258 497	13.9455	54.0	
1872	266 468	15.0634	56.5	
1873	364 086	25.6090	70.3	
1874	376 130	25.7179	68.4	
1875	388 175	27.0193	69.6	
1876	393 283	29.0635	73.9	
1877	398 390	29.0598	72.9	
1878	403 498	31.7215	78.1	
1879	408 605	31.5791	81.6	
1880	413 713	35.8879	86.7	
1881	421 350	38.2149	90.7	
1882	428 987	38.5152	89.9	

Year	Population	Av. Daily Cons. Mil. Gals.	Per Capita Daily Cons. Gals.	Per Cent Services Metered.
1883	436 624	39.6561	90.8	....
1884	444 261	31.3002	70.4	....
1885	451 898	32.3446	71.6	....
1886	467 040	34.0277	72.8	...
1887	482 181	37.4811	77.7	...
1888	497 323	41.5691	83.6	..
1889	512 464	39.9005	77.8	..
1890	527 606	42.1731	79.9	..
1891	541 876	46.7421	86.3	....
1892	556 146	51.1232	91.9	...
1893	570 417	58.1957	102.0	..
1894	584 687	56.8421	97.2	....
1895	598 957	60.2581	100.6	..
1896	615 354	68.2393	110.9	...
1897	631 751	70.3862	111.4	
1898	648 149	Records for this period not available.		
1899	664 546			
1900	680 943			
1901	690 965			
1902	700 987			
1903	711 008			
1904	721 030	100.7935	139.8	5.5
1905	731 052	102.5884	140.3	6.8
1906	747 593	103.3884	138.3	7.7
1907	764 134	109.2872	143.0	9.0
1908	780 675	110.9217	142.1	10.0
1909	797 216	105.8716	132.8	16.6
1910	813 757	98.9463	121.6	24.8
1911	830 018	96.7298	116.5	32.7
1912	862 933	102.1083	118.4	39.5
1913	879 768	90.6642	103.1	45.6
1914	896 603	93.6701	104.4	51.2
1915	913 437	88.9594	97.4	56.5
1916	915 641	92.5047	101.0	61.4
1917	917 844	94.9708	103.5	62.9
1918	920 048	108.9342	118.4	63.2
1919	922 251	102.2390	110.8	64.1
1920	924 455	108.2463	117.1	65.9

Note: East Boston supplied from the Mystic works in 1870, 1871 and 1872, but records of the quantity of water so supplied are not available. If the population of East Boston be deducted for these three years the per capita figures will be 66.2, 58.2 and 62.5 respectively.

These results, together with the estimated population and water consumption in the Metropolitan Water District and these four cities, are shown on the diagram No. 14.

It is possible, of course, that the application of meters to the remaining services in the Metropolitan Water District may reduce the consumption of water slightly within the next few years, although there is no indication from past experience that such a result is likely to be attained. It is

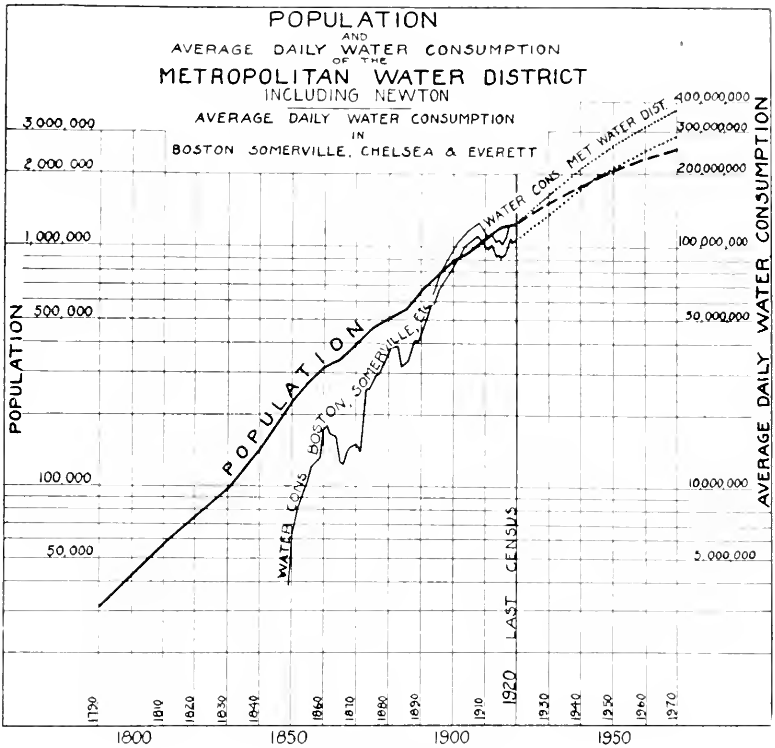


Diagram No. 14.

probable, however, that some saving can be effected in the loss of water by leakage from pipes. In estimating the future consumption of water per capita in the Metropolitan Water District it has been assumed that the amount of water used will be reduced in the next few years following the year 1920 by the application of meters to unmetered services, and that in consequence of this reduction the consumption will not again rise above 105 gallons until after 1925. Beyond that year it has been estimated that the rate of increase will average about one gallon per capita per year, being slightly greater in the earlier years of the period but growing less as time goes on. Other than the complete metering of all services, including the effective maintenance of the meter system and the prevention of losses of water by leakage so far as it is practicable to prevent them, no further means appear to be available for reducing materially the consumption of water per capita at the present time unless by some form of rationing water which under present conditions would doubtless be deemed impracticable and objectionable. On the basis of this estimate and using the estimates of population already given, the quantity of water required for the supply of the Metropolitan Water District for the next 50 years would be about as shown in the following table:

TABLE SHOWING POPULATION, WATER CONSUMPTION IN THOUSAND GALLONS PER DAY AND CONSUMPTION PER CAPITA IN GALLONS IN METROPOLITAN WATER DISTRICT AND IN THE CITY OF NEWTON FROM 1920–1970.

	1920*			1925			1930			1935		
	Population.	Per Cap. Cons.	Total Cons.	Population.	Per Cap. Cons.	Total Cons.	Population.	Per Cap. Cons.	Total Cons.	Population.	Per Cap. Cons.	Total Cons.
Met. Dist.	1 206 849	105.5	127 265	1 333 680	105.5	140 703	1 463 870	111.8	163 661	1 592 460	117.8	187 592
Newton	46 054	80.1	3 687	50 200	85.0	4 267	54 500	89.6	4 883	58 900	94.0	5 537
TOTAL ...	1 252 903	104.5	130 952	1 383 880	104.7	144 970	1 518 370	111.0	168 544	1 651 360	116.9	193 129
	1940			1945			1950			1955		
Met. Dist.	1 721 550	123.4	212 439	1 851 730	128.5	237 947	1 979 870	132.9	263 125	2 111 080	136.8	288 796
Newton	63 200	98.2	6 206	67 600	102.2	6 909	71 800	106.0	7 611	76 000	109.5	8 322
TOTAL ...	1 784 750	122.5	218 645	1 919 330	127.6	244 856	2 051 670	131.9	270 736	2 187 080	135.8	297 118
	1960			1965			1970					
Met. Dist.	2 241 270	140.5	314 898	2 373 500	144.0	341 784	2 501 170	147.3	368 422			
Newton	80 300	112.5	9 034	84 500	115.5	9 760	88 800	118.5	10 523			
TOTAL ..	2 321 570	139.5	323 932	2 458 000	143.0	351 544	2 589 970	146.3	378 945			

* 1920 figures actual; others estimated.

Capacity of the Present Sources of Water Supply of the Metropolitan Water District.

The sources of water supply owned and controlled by the Metropolitan District at the present time are:

(1) Wachusett and Sudbury Reservoirs, including Framingham Reservoir No. 3;

(2) The southern portion of the Sudbury River above Framingham, including Framingham Reservoirs 1 and 2, and the Ashland, Hopkinton and Whitehall Reservoirs;

(3) Lake Cochituate in Natick and Wayland.

The elevation, area and capacity of the various reservoirs on all these watersheds together with the drainage area of each is shown in the following table:

Reservoir.	Elevation* of High Water.	Area of Reservoir Sq. Mi.	Total Storage Capacity Mil. Gals.	Area of Watershed including Reservoir Sq. Mi.
Wachusett	395.00**	6.46	64 968.0	108.84†
Sudbury	260.00	2.21	7 253.5	22.28
Framingham No. 3	186.74	0.39	1 199.7	5.40
Total		9.06	73 421.2	136.52
Ashland	225.21	0.27	1 416.4	6.43
Whitehall	337.91	0.94	1 256.9	4.35
Hopkinton	305.00	0.30	1 520.9	5.86
Framingham No. 2	177.87	0.21	529.9	28.50
Framingham No. 1	169.32	0.23	289.9	1.84
Cochituate	144.36	1.14	2 097.1	17.58
Farm Pond	159.25	0.26	167.5	0.54
Total		3.35	7 278.6	65.10

Since the Metropolitan water works was established and water first used from the Nashua River on January 1, 1898, the water supply of the district has been obtained very largely from the Wachusett Reservoir, Sudbury Reservoir and Framingham Reservoir No. 3 though at times large quantities of water have been drawn from the other sources; as, for example, in the very dry year of 1911 about 40 per cent of the water used in the Metropolitan Water District was drawn from the Sudbury and Cochituate sources. The quantity of water used from the Wachusett and North Sudbury sources in 1920 was equal to and in fact probably somewhat in excess of their safe capacity in a period of very dry years. Consequently as the consumption of water increases hereafter it will be necessary to draw more and more water from the Cochituate and southern Sudbury sources.

Lake Cochituate furnishes water of very poor quality which, though not very highly colored, contains much organic matter and is usually affected by

* Elevation in feet above Boston City Base.

** It is possible, by use of two flashboards, to raise the water to elevation 397. At that elevation the capacity of the reservoir would be 67 686.1 million gallons.

† Exclusive of areas diverted by the city of Worcester amounting to 9.35 square miles.

an objectionable taste and odor. The water of the southern Sudbury sources is for the most part highly colored and is also affected by tastes and odors. Both the southern Sudbury and Cochituate watersheds, especially the latter, contain large populations per square mile, but while the pollution of Lake Cochituate enters largely at its extreme southerly end the water is drawn from the northerly basin of the lake. The conditions in the southern Sudbury watershed are quite different. The large reservoirs on the Sudbury River are located near the head of the watershed while at the lower end is only the small Framingham Reservoir No. 2, having a total capacity of about 530 000 000 gal. fed by a direct watershed of 28.5 sq. mi. Neither source should be used regularly for the water supply of the district unless properly filtered.

In the case of the Wachusett and Sudbury Reservoirs and Reservoir No. 3, there is also more or less population on the watersheds, especially on that of the Sudbury Reservoir; but most of the sewage is diverted from the watershed of the latter source and all of the water flowing from the densely populated portion of the city is either filtered or treated with chlorine. Long storage is also depended upon both for protection of the supply from the effects of possible pollution and for the improvement of the quality of the water which long storage affords. It has accordingly been assumed in estimating the safe capacity of the Metropolitan sources that enough water will be retained in the Wachusett and Sudbury Reservoirs and in Reservoir No. 3 to secure efficient purification by storage and render the water safe and acceptable for use; and that the water of the southern Sudbury and Cochituate sources will be purified by filtration whenever it becomes necessary to use them again for the supply of the district. For these reasons, in estimating the combined yield of the various watersheds allowance has been made for retaining in Wachusett Reservoir, Sudbury Reservoir and in Reservoir No. 3 a total of something over 20 000 000 000 gal., and in the other reservoirs of the southern Sudbury and Cochituate system about 1 400 000 000 gal., a large part of which would remain in Lake Cochituate and should be retained there to prevent objectionable odors from the exposed bottom of the lake. These allowances especially in the case of the Wachusett Reservoir are less than desirable and if the water were drawn to so low a level the color would probably increase so as to become noticeable in the water supplied to the district.

The estimated gross yield of all the present sources of water supply of the district as given in the State Board of Health report in 1895 was 173 000 000 gal. per day. Since that time water from a part of the Wachusett watershed has been diverted for the use of the city of Worcester and the area of the Wachusett watershed reduced from 118.19 sq. mi. to 108.84 sq. mi. Not all of this water has yet been diverted but when the Pine Hill Reservoir of the city of Worcester, now under construction, is completed, it will be practicable for that city to divert the entire flow of water from the area set apart for its use in dry periods and it is consequently

essential in estimating the safe yield of the Metropolitan water works to assume that all of the water from this area will be diverted by Worcester. Allowing for this diversion the gross yield of the present source is about 169 000 000 gal. per day. The yield is of course larger than the yield of the Sudbury, Cochituate and Wachusett sources computed separately since by operating them together a larger amount can be obtained than by operating them as separate units.

Of the gross yield of 169 000 000 gal., a considerable part is diverted for various purposes, a part is lost by leakage, a further part is used for the water supply of certain cities and towns within the Metropolitan watersheds which are authorized to take water therefrom, another part is lost by leakage into sewerage systems in these watersheds by which it is diverted to points outside their limits, and there are unavoidable losses in other ways. Without going into details, these allowances aggregate about 14 500 000 gal., so that the available safe yield of all existing sources is about 154 500 000 gal. per day. This estimate has been based upon the yield in the dry period from 1908 to 1915, and no allowance has been made for a period of lower rainfall. Such dry periods have occurred some 5 or 6 times in a century, so far as rainfall records in New England show, and in some of these periods there has been a smaller precipitation, and hence no doubt a smaller yield of watersheds than in the dry period which began in 1908. It is to be noted, however, that the estimate is based on the assumption that all of the sources of water supply are available for use at all times. Under present conditions it is unsafe to use the southern Sudbury or Cochituate sources without filtration, and no provision has yet been made for treating these waters. Unless these sources are in regular use, the yield is likely to be less, and perhaps considerably less than the estimate here given.

Consumption of Water in the City of Newton.

In comparing the consumption of water in the Metropolitan Water District with the capacity of the sources, it is essential to consider the city of Newton which, though a part of the district, has continued to supply itself with water, except in emergencies, from its own sources near the Charles River, up to the present time. The capacity of these sources has recently been the subject of a careful study by the city engineer of Newton, which indicates that that city can furnish from its own works at the present time in a very dry period, if these works are used in connection with the Metropolitan Water District, about 4 000 000 gal. of water per day. Without going into details as to the capacity and probable limitations of the yield of the Newton water works sources, it may be said that the estimate of a safe yield of 4 000 000 gal. per day from the Newton sources used in connection with the sources of the Metropolitan Water District, as seems probable, appears to be a reasonable one under the conditions which exist in the Charles River valley at the present time.

Capacity of Present Sources of the Metropolitan Water District to Meet the Requirements of the District.

The estimated yield of all the sources of supply available to the Metropolitan Water District is in round numbers 154 000 000 gal. Adding to this the estimated safe yield of the sources of water supply of the city of Newton, the safe yield of all available sources of the cities and town in the district is 158 000 000 gal. per day. This amount will diminish no doubt in the future on account of increases in the amounts of water diverted for water supply by the towns now using water from the Metropolitan watersheds and also by leakage into the sewerage systems in those watersheds. The following table shows a comparison of the yield of the available sources with the estimated quantity of water required as given in the earlier portion of this report.

Table showing a Comparison of the Yield of the Metropolitan Water Supply Sources Plus those of the City of Newton and the Consumption of Water in the present Metropolitan Water District in Census Years, 1920 to 1935.

	1920*	1925	1930	1935
		(Million Gals. per Day.)		
Safe Yield of all Metropolitan sources including Newton supply	158.0	158.0	158.0	157.0**
Consumption of water in Metropolitan Water District (including Newton)	131.0	145.0	168.5	193.1
Excess	27.0	13.0	....	....
Deficiency		....	10.5	36.1

* Actual; other figures estimated.

** An allowance for a reduction of 1 000 000 gallons per day is made to provide for additional increases in the diversions of water from the Metropolitan watersheds and increasing losses by leakage.

This table shows that by the year 1930 the quantity of water required by the district on the basis of the estimates already given will exceed the safe yield of the sources of supply on an average about 10 000 000 gal. per day.

In this estimate no allowance is made for the taking of additional water from the district sources by any of the municipalities having rights reserved therein under various legislative grants which have not yet exercised such right. Rights have been reserved to some 19 municipalities but have thus far been exercised by only 9.

More important still, however, is the fact that no allowance is made in these calculations for supplying water to municipalities outside of the limits of the present district but within the 10-mile radius from the State House which may join the district if they so elect. There are also several other municipalities which may desire to take water from the district and which may properly be supplied therefrom under the terms of the

Metropolitan water act. While neither Worcester nor the other municipalities outside the present limits of the Metropolitan Water District are members of that district, they nevertheless have substantial claims upon a water supply from or in connection with the district, and it is essential that their possible requirements shall be taken into account in any consideration of the future water supply of the Metropolitan Water District. It is not practicable, however, within the limits of this paper to consider except in the briefest way the possible needs and requirements of the municipalities not now connected with the Metropolitan Water District but which are likely to require a water supply from the district in some future time.

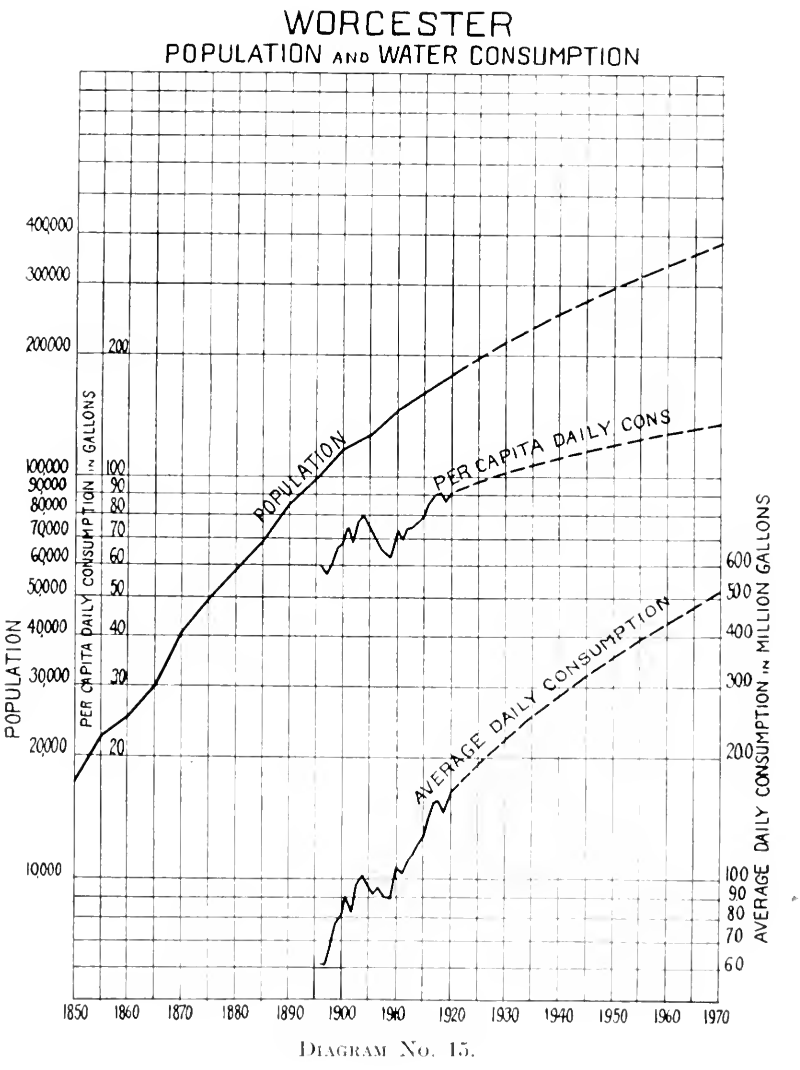


Diagram No. 15.

Water Supply of the City of Worcester.

First in importance among the municipalities requiring consideration in this connection is the city of Worcester which has grown steadily for many years and in which the per capita consumption of water has been increasing quite rapidly in spite of the fact that more than 90 per cent of the services have been metered for the past 26 years. These results, together with the estimated population and water consumption are shown in diagram No. 15.

An investigation for an additional water supply for the city of Worcester was made by a special commission of that city under the authority of Chapter 176 of the Acts of the year 1918 and a report of that commission is printed as Senate Document No. 346 of the year 1920. This report presents in some detail the results of studies of the sources of water supply in the region about the city of Worcester and recommends that that city be authorized to take an additional supply from Quinepoxet Pond and a neighboring stream, tributaries of the Quinepoxet River which is one of the main feeders of the Wachusett Reservoir. The portion of the Wachusett watershed from which the city of Worcester desires to take water has an area of about 17.4 sq. mi. or about 15.9 per cent of the area remaining tributary to the Wachusett Reservoir, after which the diversion of the watershed of Pine Hill and Kendall reservoirs was authorized in the original Metropolitan Water Act.

That Act, in Section 22, states that " the towns of Clinton, Sterling, Boylston, West Boylston, Lancaster, Holden, Rutland, Princeton and Leicester and the city of Worcester may take from the south branch of the Nashua River above the dam of the proposed reservoir on said river so much of the water thereof as they have already been or may hereafter be authorized by the legislature to take for supplying their inhabitants with water, etc." The act goes on to provide for payment for any water that may be diverted under the act. In the report of the State Board of Health of 1895 relative to a Metropolitan water supply a certain area is marked on the plan of the Nashua River watershed as "recommended for the city of Worcester" and by the provisions of a later act the city was granted the right to take water from that area.

The present sources of water supply of the city of Worcester are a group of storage reservoirs on Kettle Brook in Leicester and Paxton, on Lynde Brook in Leicester, on Tatnuck Brook in Holden, and on certain tributaries of the Quinepoxet River within the watershed of the Wachusett Reservoir. The Kettle and Lynde Brook sources supply the high service districts, while the reservoirs on Tatnuck Brook known as Holden Reservoirs Nos. 1 and 2, supplemented with water from Kendall Reservoir within the Wachusett watershed which is diverted into the upper end of Holden Reservoir No. 1, supply the low service districts. A reservoir much larger than any now in use, known as the Pine Hill Reservoir, is being constructed

within the portion of the Wachusett watershed assigned to Worcester. The water of this reservoir will flow by gravity to Kendall Reservoir and thence to the Holden Reservoirs.

The area and capacity of the various reservoirs are given in the following table.

WORCESTER

Reservoir.	Elevation.** (Feet)	Area of Reservoir (Sq. Mi.)	Total Storage Capacity (Mil. Gals.)	Area of Watershed including Reservoir (Sq. Mi.)
Kettle Brook, No. 4	1 082.74	0.186	514	1.805
Kettle Brook, No. 3	1 040.00	0.058	152	0.722
Kettle Brook, No. 2	988.50	0.048	127	0.569
Kettle Brook, No. 1	845.36	0.007	19	1.002*
Lynde Brook	822.94	0.206	701	2.921
Upper Holden	750.88	0.211	794	4.555
Lower Holden	718.80	0.089	283	0.676
Kendall	814.00	0.273	850	2.451
Pine Hill	910.00	0.720	3 000	6.899
		1.798		21.600

* Includes Peter Brook.
** Above Mean Sea Level.

The safe yield of present sources of water supply of the city of Worcester is 16 million gallons, but with the completion of the Pine Hill Reservoir the yield will be increased to 19.3 million gallons per day. At the rate of increase in the use of water maintained by the city for many years, the present sources with the Pine Hill Reservoir completed will be sufficient for the requirements of the city for about 5 or 6 years only.

The city of Worcester now desires an additional water supply. It is probable, however, that the city of Worcester will eventually supply water to some of the adjacent municipalities. Its population and the quantity of water used by the city in census years since 1900 and the estimated quantity required until 1970 are shown in the following table.

WORCESTER

POPULATION, DAILY WATER CONSUMPTION AND PER CAPITA CONSUMPTION, 1900–1920.

Year	Population.	Per Capita Consumption (Gals.)	Total Consumption (Gals.)
1900	118 421	69.0	8 153 000
1905	128 135	75.0	9 581 000
1910	145 986	74.0	10 805 000
1915	162 697	79.0	12 848 000
1920	179 754	91.9	16 515 000

Estimated Population, Daily Water Consumption and Per Capita Consumption 1920–1970.

	Population.	Per Capita Consumption (Gals.).	Total Consumption (Gals.).
1920*	179 754	91.9	16 515 000
1925	198 500	96.8	19 215 000
1930	217 500	101.6	22 098 000
1935	237 000	106.2	25 169 000
1940	257 100	111.0	28 538 000
1945	277 800	115.5	32 086 000
1950	298 000	120.1	35 790 000
1955	318 800	124.3	39 627 000
1960	339 600	128.6	43 673 000
1865	360 000	132.8	47 808 000
1970	380 700	137.0	52 156 000

* 1920 figures actual; others estimated.

Probable Requirements of Cities and Towns Within 10 Miles of the State House not at Present Included in the Metropolitan Water District.

The cities and towns within the 10-mile limit from the State House which are eligible to join the Metropolitan Water District under the provisions of the Metropolitan Water Act are the following:

Cambridge	Canton	Hull	Saugus
Brookline	Braintree	Wakefield	Winchester
Wellesley	Weymouth	Woburn	Waltham
Needham	Hingham	Lynn	Dedham

The Metropolitan Water Act, Chapter 488 of the Acts of the year 1895, provides that the Metropolitan Water Board "shall on application admit any other city or town, any part of which is within ten miles of the State House, into said water district, etc. . . . on such payment of money as said board may determine." As already stated a number of cities and towns have joined the District since the Metropolitan Water Act was passed and it is interesting to examine the conditions under which those municipalities were admitted to the district and the entrance fee paid for the purpose.

The towns which have been admitted since the district was created and the amounts paid by each are as follows:

Arlington, admitted Jan. 31, 1899, entrance fee $15 000 and property valued at $15 000.
Lexington, admitted Feb. 13, 1903, entrance fee $27 250.
Milton, admitted March 10, 1903, entrance fee $10. (Previous payments by Milton Water Company being a consideration in part for admittance.)
Nahant, admitted Sept. 13, 1898, entrance fee $20 000 and an annual payment of $800 until Swampscott began to buy water.
Quincy, admitted June 24, 1897, entrance fee $5 000.
Stoneham, admitted May 23, 1901, entrance fee $30 000.
Swampscott, admitted May 3, 1909, entrance fee $90 000.

It will be seen from this record that the last town admitted was Swampscott in 1909, 13 years ago, and the last one previous to Swampscott was Milton admitted in 1903, 19 years ago. A number of cities and towns have since sought to join the district but have been deterred mainly by the large entrance fee likely to be assessed upon them for admission.

This question of the charge for the admission of other cities and towns to the Metropolitan Water District is constantly arising. Hitherto it has been customary to require the municipality applying for entrance to the district to pay its proportionate share of the accumulated sinking fund as determined by the Commission, with possibly some extra charge for the necessary works required for a physical connection with the District. The method was a satisfactory one in the beginning at least, because for those who came in early the share of the sinking fund was comparatively small, and at that time the works were ample for all requirements.

In the year of the last admission, in 1909, the sinking fund amounted to $7 203 406.08. With the increase in the total amount of the sinking fund which amounted in 1920 to $16 953 165.15 the charge for admission of additional municipalities has been necessarily a constantly increasing one; yet, while the charge for admission is increasing, the prospective benefit of the works to the entering municipality, as well as their practical value, is decreasing, since their capacity is being approached and some obsolescence has occurred.

The matter has reached a stage where the cost of admission has apparently become a serious deterrent to the addition of other municipalities to the Metropolitan Water District. In the end of course, within a comparatively few years, the sinking fund will be used for the payment of the bonds, the debt will be fully paid, and the basis for this method of determining the charge for admission of other municipalities to the district will disappear. With the increase in the size of the works which must inevitably be made and the material addition to the cost which must come in the immediate future, it seems necessary that a new basis for the charge for entrance to the district should be devised.

The Metropolitan water act gives the Metropolitan District Commission the sole right to determine the charges for admission of other cities and towns to the Metropolitan Water District; but a change in the law could probably be made if agreed to by the Metropolitan District Commission, and an arrangement might be reached which would be a reasonable one and would be generally acceptable. The charge based on the past methods of computation are regarded, probably with reason, as excessive at the present time. The method should be revised as promptly as possible in the interests of all concerned. The matter is a most important one and its present status unsatisfactory.

The aggregate population in 1920 of the sixteen municipalities which though eligible have not joined the district, was 391 448; and the total quantity of water consumed by them was 34 241 000 gal. per day, or 87.4 gal. per person per day. The population, per capita consumption, per cent of metered services and total consumption of water in each of these municipalities, so far as the records are available in the last 20 years, are shown in the following table.

Population and Consumption of Water of 16 Municipalities Within 10 Miles of State House.

1900–1920.

	1900			1901		
	Population.	Per Capita Consumption. (Gals.)	Total Consumption. (1000 Gals.)	Population.	Per Capita Consumption. (Gals.)	Total Consumption. (1000 Gals.)
Cambridge	91 886	79.0	7 304	92 996	83.0	7 690
Brookline	19 935	97.0	1 941	20 635	92.0	1 902
Wellesley	5 072	47.0	239	5 295	46.0	244
Needham	4 016	56.0	224	4 070	57.0	231
Canton*	4 584	46.0	209	4 608	43.0	197
Braintree	5 981	91.0	544	6 161	78.0	479
Weymouth**	11 324	.....	610	11 376	.....	630
Hingham†	5 059	50.8	257	5 011	51.5	258
Hull†	1 703	145.0	247	1 774	146.8	260
Wakefield(e)	9 290	60.0	557	9 500	60.0	570
Woburn	14 254	78.0	1 117	14 284	78.0	1 120
Lynn, Saugus	73 597	64.0	4 680	75 537	60.0	4 506
Winchester(f)	7 248	.....	225	7 447	.....	240
Waltham	23 481	90.0	2 118	24 041	95.0	2 291
Dedham	7 457	79.0	586	7 520	83.0	621
Totals	284 887	73.2	20 858	290 255	73.2	21 239

	1902			1903		
Cambridge	94 105	86.0	8 099	95 215	91.0	8 642
Brookline	21 335	92.0	1 961	22 036	96.0	2 116
Wellesley	5 519	47.0	257	5 742	51.0	294
Needham	4 123	67.0	275	4 177	71.0	295
Canton	4 631	49.0	226	4 655	55.0	254
Braintree	6 340	85.0	538	6 520	88.0	574
Weymouth	11 428	.....	650	11 481	.....	670
Hingham	4 963	52.2	259	4 915	52.8	260
Hull	1 846	148.5	274	1 917	150.2	288
Wakefield	9 681	60.0	577	9 877	60.0	588
Woburn	14 313	83.0	1 193	14 343	94.0	1 351
Lynn, Saugus	77 476	60.0	4 684	79 416	65.0	5 138
Winchester	7 646	.....	250	7 844	.....	255
Waltham	24 601	99.0	2 435	25 162	90.0	2 254
Dedham	7 584	89.0	675	7 647	104.0	796
Totals	295 591	75.6	22 353	300 947	79.0	23 775

For references, see page 230.

	1904			1905		
	Population	Per Capita Consumption. (Gals.)	Total Consumption. (1000 Gals.)	Population	Per Capita Consumption. (Gals.)	Total Consumption (1000 Gals.)
Cambridge	96 321	92.0	8 847	97 134	92.0	8 973
Brookline	22 736	103.0	2 348	23 436	95.0	2 228
Wellesley	5 966	52.0	313	6 189	47.0	289
Needham	4 230	65.0	274	4 284	66.0	284
Canton	4 678	62.0	288	4 702	63.0	296
Braintree	6 699	88.0	592	6 879	87.0	600
Weymouth	11 533	.	690	11 585	.	700
Hingham	4 867	53.5	260	4 819	54.1	261
Hull	1 989	152.0	302	2 060	153.8	317
Wakefield	10 072	65.0	655	10 268	73.0	747
Woburn	14 372	98.0	1 413	14 402	103.0	1 490
Lynn / Saugus	81 355	66.0	5 333	83 295	59.0	4 924
Winchester	8 043	.	260	8 242	.	270
Waltham	25 722	81.0	2 073	26 282	79.0	2 070
Dedham	7 711	135.0	1 041	7 774	135.0	1 046
Totals	306 297	80.6	24 689	311 651	78.6	24 495
	1906			**1907**		
Cambridge	98 915	96.0	9 491	100 396	109.0	10 992
Brookline	24 307	84.0	2 048	25 178	89.0	2 236
Wellesley	6 034	45.0	273	5 879	52.0	305
Needham	4 432	77.0	342	4 581	69.0	315
Canton	4 721	49.0	230	4 740	51.0	244
Braintree	7 116	77.0	549	7 354	66.0	484
Weymouth	11 848	. . . .	720	12 109	. . .	740
Hingham	4 848	54.7	265	4 877	55.4	270
Hull	2 069	155.5	322	2 077	157.2	327
Wakefield	10 495	69.0	729	10 722	68.0	724
Woburn	14 583	104.0	1 513	14 764	114.0	1 682
Lynn / Saugus	86 113	60.0	5 133	88 930	68.0	6 018
Winchester	8 455		280	8 669		290
Waltham	26 592	73.0	1 941	26 903	84.0	2 272
Dedham	8 076	95.0	770	8 378	104.0	868
Totals	318 604	77.2	24 606	325 557	85.3	27 767
	1908			**1909**		
Cambridge	101 877	103.0	10 450	103 358	95.0	9 859
Brookline	26 050	90.0	2 353	26 921	86.0	2 311
Wellesley	5 723	54.0	310	5 568	58.0	324
Needham	4 729	75.0	355	4 878	69.0	335
Canton	4 759	59.0	280	4 778	60.0	287
Braintree	7 591	56.0	424	7 829	63.0	493
Weymouth	12 371		770	12 633		790
Hingham	4 907	56.0	275	4 936	56.7	280
Hull	2 086	159.0	332	2 091	160.8	337
Wakefield	10 950	67.0	730	11 177	62.0	698
Woburn	14 946	111.0	1 652	15 127	119.0	1 803
Lynn / Saugus	91 718	67.0	6 118	91 565	68.0	6 394
Winchester	8 882		300	9 095		310
Waltham	27 213	83.0	2 266	27 524	87.0	2 382
Dedham	8 680	109.0	917	8 982	129.0	1 160
Totals	332 512	82.9	27 562	339 165	81.8	27 766

	1910			1911		
	Population.	Per Capita Consumption. (Gals.)	Total Consumption. (1000 Gals.)	Population.	Per Capita Consumption. (Gals.)	Total Consumption. (1000 Gals.)
Cambridge	104 839	100.0	10 458	105 636	97.0	10 226
Brookline	27 792	89.0	2 476	28 932	90.0	2 605
Wellesley	5 413	61.0	331	5 618	63.0	354
Needham	5 026	66.0	332	5 329	58.0	308
Canton	4 797	61.0	293	4 962	65.0	323
Braintree	8 066	81.0	653	8 321	63.0	524
Weymouth	12 895	.....	810	13 110	.....	840
Hingham	4 965	57.3	284	5 025	57.9	291
Hull	2 103	162.5	342	2 140	164.2	351
Wakefield	11 404	61.0	694	11 679	57.0	664
Woburn	15 308	139.0	2 134	15 528	120.0	1 856
Lynn, Saugus	97 383	72.0	7 027	99 112	68.0	6 710
Winchester	9 309	.....	325	9 448	.....	340
Waltham	27 834	88.0	2 443	28 298	89.0	2 513
Dedham	9 284	129.0	1 202	9 636	128.0	1 235
Totals	346 418	86.0	29 804	352 774	82.6	29 140
	1912			1913		
Cambridge	106 432	101.0	10 793	107 229	98.0	10 549
Brookline	30 071	88.0	2 633	31 211	87.0	2 708
Wellesley	5 823	64.0	374	6 029	65.0	389
Needham	5 632	63.0	356	5 936	58.0	344
Canton	5 127	75.0	386	5 293	64.0	338
Braintree	8 577	68.0	587	8 832	62.0	545
Weymouth	13 325	.	870	13 539	.....	900
Hingham	5 085	58.6	298	5 144	59.2	304
Hull	2 178	166.0	362	2 215	167.8	372
Wakefield	11 955	60.0	713	12 230	56.0	684
Woburn	15 749	128.0	2 014	15 969	109.0	1 744
Lynn, Saugus	100 841	67.0	6 750	102 571	62.0	6 366
Winchester	9 587	....	350	9 727	....	360
Waltham	28 762	95.0	2 743	29 226	93.0	2 714
Dedham	9 988	116.0	1 156	10 339	108.0	1 121
Totals	359 132	84.6	30 385	365 490	80.6	29 438
	1914			1915		
Cambridge	108 025	94.0	10 137	108 822	82.0	8 957
Brookline	32 350	89.0	2 875	33 490	82.0	2 750
Wellesley	6 234	64.0	398	6 439	73.0	470
Needham	6 239	63.0	395	6 542	62.0	405
Canton	5 458	53.0	291	5 623	56.0	313
Braintree	9 088	60.0	549	9 343	53.0	498
Weymouth	13 753	.....	930	13 969	69.0	966
Hingham	5 204	59.9	312	5 264	60.5	318
Hull	2 253	169.5	382	2 290	171.2	392
Wakefield	12 506	47.0	590	12 781	46.0	592
Woburn	16 190	116.0	1 883	16 410	122.0	1 996
Lynn, Saugus	104 300	65.0	6 761	106 029	60.0	6 385
Winchester	9 866	....	380	10 005	....	395
Waltham	29 690	83.0	2 465	30 154	76.0	2 294
Dedham	10 691	99.0	1 054	11 043	88.0	973
Totals	371 847	79.1	29 402	378 204	73.3	27 704

	1916			1917		
	Population.	Per Capita Consumption. (Gals.)	Total Consumption. (1000 Gals.)	Population.	Per Capita Consumption. (Gals.)	Total Consumption (1000 Gals.)
Cambridge	108 996	89.0	9 711	109 171	89.0	9 712
Brookline	31 342	83.0	2 838	35 193	87.0	3 078
Wellesley	6 396	78.0	498	6 353	86.0	544
Needham	6 636	62.0	413	6 730	56.0	379
Canton . . .	5 687	53.0	301	5 752	51.0	296
Braintree . .	9 590	65.0	625	9 838	60.0	588
Weymouth	14 187	65.0	918	14 404	78.0	1 127
Hingham .	5 332	61.1	326	5 400	61.8	334
Hull	2 186	173.0	378	2 082	174.8	364
Wakefield	12 830	48.0	619	12 879	43.0	554
Woburn	16 443	136.0	2 229	16 476	124.0	2 046
Lynn . . / Saugus	106 828	66.0	7 065	107 626	68.0	7 316
Winchester	10 101	. . . . .	410	10 197	. . .	430
Waltham .	30 306	75.0	2 258	30 458	74.0	2 249
Dedham . . .	10 993	92.0	1 008	10 943	95.0	1 041
Totals . .	380 853	77.7	29 597	383 502	78.4	30 058

	1918			1919		
Cambridge . . .	109 345	102.0	11 127	109 520	96.0	10 513
Brookline .	36 045	87.0	3 144	36 896	90.0	3 309
Wellesley	6 310	86.0	545	6 267	83.0	522
Needham	6 824	68.0	462	6 918	57.0	396
Canton	5 816	68.0	393	5 881	75.0	439
Braintree	10 085	72.0	722	10 333	62.0	637
Weymouth	14 622	99.0	1 445	14 839	81.0	1 208
Hingham	5 468	62.4	341	5 536	63.1	349
Hull	1 979	176.5	349	1 875	178.2	334
Wakefield .	12 927	61.0	786	12 976	45.0	584
Woburn	16 508	141.0	2 320	16 541	109.0	1 796
Lynn . . / Saugus	108 425	77.0	8 374	109 223	74.0	8 018
Winchester	10 293	42.0	435	10 389	43.0	444
Waltham .	30 611	82.0	2 510	30 763	63.0	1 952
Dedham .	10 892	104.0	1 133	10 842	73.0	796
Totals .	386 150	88.3	34 086	388 799	80.6	31 327

	1920		
	Population.	Per Capita Consumption. (Gals.)	Total Consumption. (1000 Gals.)
Cambridge	109 694	104.2	11 435
Brookline	37 748	91.4	3 451
Wellesley	6 224	86.1	536
Needham	7 012	64.2	450
Canton	5 945	70.5	419
Braintree	10 580	70.1	742
Weymouth	15 057	97.0	1 464
Hingham	5 604	63.7	357
Hull	1 771	180.0	319
Wakefield	13 025	47.6	620
Woburn	16 574	127.0	2 104
Lynn, Saugus	110 022	82.8	9 113
Winchester	10 485	45.0	472
Waltham	30 915	63.4	1 960
Dedham	10 792	74.0	799
Totals	391 448	87.5	34 241

* Canton — 1913 and 1920 water consumption figures estimated.
** Weymouth — All water consumption figures estimated, except 1915-20, inclusive.
† Hingham and Hull — Water consumption figures estimated.
(e) Wakefield — 1900 and 1901 estimated figures for water consumption.
(f) Winchester — All water consumption figures estimated, except 1918 and 1919.

Most of these municipalities must inevitably obtain all or part of their water supplies from the Metropolitan Water District in the not distant future, that is within the next 10 or 15 years, though some of them have water enough to last for a longer time. Out of the total population of about 391 000 in these cities and towns in 1920, it is probable that about two-thirds or about 270 000 will require a water supply from the Metropolitan Water District within the next 10 or 15 years, the length of this period depending largely upon the rainfall. These suburban municipalities use less water per capita of course than the present Metropolitan Water District and in estimating future requirements of the district including these municipalities a smaller consumption of water is allowed for than in the case of the district alone.

Besides the municipalities within the 10-mile limit, there are others beyond that limit which may require a water supply from the Metropolitan District within the next 10 to 15 years, some for the reason that their water supplies are limited and are likely soon to become exhausted, others because of the poor quality of the waters now used, and still others because of the expense of maintaining their present works. The more important of these municipalities contained an aggregate population in 1920 of 44 120.

Without going into the matter further and omitting any consideration of the remaining towns which have rights to take water from the Metropolitan watersheds and omitting also those towns which will naturally take their water supplies at some time in the future from the city of Worcester, there is a total population of some 570 000 which, including the city of Worcester, either have rights in the Metropolitan watersheds or may claim the right to a supply of water from the Metropolitan Water District. A number of these places, however, can probably obtain a sufficient quantity of water from their own sources for many years.

It is not practicable within the limits of this paper to give a detailed statement as to the water supplies of all of the cities and towns which may desire to join the Metropolitan Water District or may require a water supply therefrom within the not distant future. With the coming of a dry period there is likely to be a large increase in water supply requirements from the district sources coming from territory outside its present limits, and the demands of outside cities and towns for water for use in emergencies could not of course be denied. It is necessary, however, that all local sources which are still suitable for use shall be continued in use so long as practicable and only surplus requirements drawn from the works of the Metropolitan Water District until the district sources have been materially increased.

Including the city of Worcester and about two-thirds of the population in the municipalities within the 10-mile limit of the State House which are not at present connected with the Metropolitan Water District and omitting any provision for municipalities outside that limit, the total population to be supplied and the quantity of water which is likely to be required for the next 15 years would be about as shown in the following table:

	1920			1925		
	Population.	Per Capita Daily Consumption. (Gals.)	Average Daily Consumption. (Gals.)	Population.	Per Capita Daily Consumption (Gals.)	Average Daily Consumption. (Gals.)
Metropolitan District as supplied	1 206 849	105.5	127 265 000	1 333 680	105.5	140 703 000
Newton	46 054	. .	3 687 000	50 200	. .	4 267 000
TOTAL	1 252 903	104.5	130 952 000	1 383 880	104.8	144 970 000
Near-by cities and towns	272 840		24 659 000	299 276		28 288 000
TOTAL	1 525 743	102.0	155 611 000	1 683 156	102.9	173 258 000
Worcester	179 754		16 515 000	198 500		19 215 000
TOTAL	1 705 497	100.9	172 126 000	1 881 656	102.3	192 473 000

	1930			1935		
Metropolitan District as supplied	1 463 870	111.8	163 661 000	1 592 460	117.8	187 592 000
Newton	54 500	....	4 883 000	58 900	...	5 537 000
Total	1 518 370	111.0	168 544 000	1 651 360	116.9	193 129 000
Near-by cities and towns	327 512	.....	32 249 000	355 358	...	36 260 000
Total	1 845 882	108.8	200 793 000	2 006 718	114.3	229 389 000
Worcester	217 500	....	22 098 000	237 000	..	25 169 000
Total	2 063 382	108.0	222 891 000	2 243 718	113.5	254 558 000

The quantity of water which may be required from the sources of water supply of the Metropolitan District by the population which is likely to take water from the district within the next 15 years, as compared with the capacity of available sources, is shown in the following table:

	Million Gallons per Day.			
	1920	1925	1930	1935
Safe yield of sources of Metropolitan Water District plus Newton	158.0	158.0	158.0	157.0
Safe yield of sources of nearby cities and towns, — which can probably be retained in use	22.8	22.8	22.8	22.8
Total Safe Yield	180.8	180.8	180.8	179.8
Requirements of Metropolitan Water District and Newton	131.0	145.0	168.5	193.1
Requirements of nearby cities and towns	24.6	28.3	32.3	36.3
Total Requirements	155.6	173.3	200.8	229.4
Excess of safe yield over requirements of District alone	27.0	13.0	....	....
Deficiency	.....	....	10.5	36.1
Excess of safe yield over requirements with adjacent municipalities added	25.2	7.5	.....	....
Deficiency	....	..	20.0	49.6
Safe yield of present sources which can be retained in use, with Worcester added	200.1	200.1	200.1	199.1
Total requirements, with Worcester added	172.1	192.5	222.9	254.6
Excess of safe yield over requirements	28.0	7.6	...	....
Deficiency	.....	.....	22.8	55.5

It will be seen from the foregoing table that the consumption of water in the Metropolitan Water District at the probable rate of increase indicated by past experience is likely to exceed the safe capacity of the present sources in the year 1930 by about 10 million gallons per day. If other cities and

towns within the 10-mile radius from the State House should join the district and take only their surplus requirements therefrom beyond the capacity of their present sources, the deficiency in the supply of the Metropolitan District in that year may reach 20 000 000 gal. per day without allowance for the city of Worcester. The requirements of the district alone as at present constituted are likely to reach to from 30 000 000 to 35 000 000 gal. per day in excess of the yield of present sources by 1935 and to over 80 000 000 gal. per day 10 years later. Of course if the city of Worcester and other municipalities should be added to the district or should take water from the District sources, as inevitably will be the case, these amounts would be materially exceeded.

Present Situation of the Metropolitan Water District and Other Municipalities in its Neighborhood in Eastern Massachusetts with Regard to Water Supply.

The seriousness of the situation with regard to water supply in eastern Massachusetts, that is in the Metropolitan Water District and the adjacent territory including the city of Worcester, is well illustrated by considering what is likely to happen in this territory should a dry period occur within the next 10 to 15 years, assuming that all available sources, both of the district and the other cities and towns, should be used to their fullest practicable capacity, and assuming also that a new supply of 33 000 000 gal. per day will be introduced from the Ware River to be referred to later as speedily as practicable. The safe yield of present sources of supply for the Metropolitan District alone is sufficient until the year 1928 if no other municipalities are added. If a severe drought should occur at about that time the district supplies might be exhausted as early as 1926. If a supply of 33 000 000 gal. per day should be introduced from the Ware River it would be sufficient for the district alone until the year 1935, but if the city of Worcester and half of the cities and towns in the neighborhood of the district which seem likely to need water with the next dry period should be added to the district the supply would be sufficient only until about 1932. Even if it were assumed that there will be no increase whatever hereafter in the consumption of water per capita in the Metropolitan Water District, the consumption of water in that district including the nearby cities and towns likely to require water therefrom and the city of Worcester would reach the safe capacity of all available sources, even with an additional supply of 33 000 000 gal. from the Ware River, by 1936. In other words, if a supply of 33 000 000 gal. per day should be introduced as soon as possible from the Ware River, a still further supply would be needed by 1931, and even if the consumption of water per capita in the present Metropolitan District can be kept from increasing beyond the figure of 1920, a further additional supply would be needed by 1936, even though all of the present available sources, so far as possible, should be retained in use.

Circumstances which Affect the Selection of Water Supply for the Metropolitan District.

There have been marked changes in the conditions affecting the use of inland waters in Massachusetts since the earlier water supply projects were considered. Massachusetts is an industrial State and its rivers are most important sources of power, the value of which has increased with the great increase that has taken place in the demand for power and the cost of fuel. But not only is the water of the rivers of great value for power but also for manufacturing and mechanical uses, and large quantities of water are used for these purposes in some of the more important industries of the State. Furthermore, with the growth in population and the increase in industry, especially within the past 30 years, there has been a great increase in the quantity of sewage and industrial wastes requiring disposal in the river valleys of the State.

River sanitation had hardly been thought of in this country 50 years ago, and the first general laws of importance relating to that subject were not enacted until 1886 and 1888. Knowledge of its requirements was still in its infancy when the investigations for the present Metropolitan water system were begun nearly 30 years ago and even at the present day the progress attained still leaves much room for improvement.

While works for treating sewage and manufacturing wastes are common as compared with the conditions 30 years ago, these wastes still find their way into the streams in some cases with more or less effective purification but commonly with none at all. Under these conditions, the question of the diversion of water from a given watershed may affect in a much greater degree than was the case 30 years or more ago the conditions in the valley of a river below a proposed point of diversion. These considerations have a most important effect upon the availability of many of the rivers of the State for use as sources of water supply.

The diversion of the flow of water from any considerable portion of the watershed of many of the streams, besides the effect it may have on the use of the streams for other purposes, especially in the drier part of the year, means a reduction in the water available for the dilution of effluents discharged lower down and an increase in the difficulty and expense of maintaining proper sanitary conditions in such streams. In some of the river valleys great changes have taken place in respect to the use, and it must be admitted the abuse, of the streams in the past 30 years which require careful consideration in connection with any plan for diverting water from such streams for water supply uses, since such diversions may involve large claims for damages wholly aside from the use of the streams for power or other industrial purposes. These considerations affect materially the advantages of the use of some of the proposed sources of water supply considered available at an earlier day.

Sources of Water Supply Considered.

The Charles River is one of the streams which have been mentioned as possible additional sources of water supply for the Metropolitan Water District. It is an excellent example of the changes that have taken place since its use was first seriously proposed as a source of water supply for the city of Boston in 1874. The river above the Boston Manufacturing Company's dam at Waltham drains an area of about 248 sq. mi., but as one-third of the flow is diverted into Mother Brook at Dedham, the effective watershed at Waltham is only 182 sq. mi. At the present time 17 cities and towns obtain their water supply from this watershed, the population of these municipalities and the quantity of water used in each in 1895 and in 1920, so far as information is available, being shown in the following table:

Supply Introduced in.	Municipality.	Population Supplied. 1895	Population Supplied. 1920	Consumption in Gallons per Day. 1895	Consumption in Gallons per Day. 1920
1873	Waltham	20 876	30 915	1 222 000	1 960 000
1856	Cambridge	81 643	109 694	6 074 000	11 435 000
1874	Lincoln	1 111	1 042	144 500*	221 000
1896	Weston	....	2 282	....	159 000
1884	Wellesley	4 229	6 224	175 000	536 000
1876	Newton	27 590	46 054	1 801 000	3 687 000
1890	Needham	3 511	7 012	139 000	450 000
1875	Brookline	16 164	37 748	1 318 000	3 451 000
1881	Dedham	7 211	10 792	419 000	799 000
1891	Holliston	2 718	2 707	79 000	119 000
1891	Millis	1 006	1 485	33 200*	61 000
1889	Medfield	1 872	1 900**	56 000*	76 000*
1911	Medway	2 913	2 956	90 300*	122 000
1881	Milford & Hopedale	10 336	16 248	527 000	987 000
1884	Franklin	5 136	6 497	201 000	513 000
1908	Wrentham	....	2 808		89 000
		186 316	286 364	12 279 000	24 665 000

* Estimated. ** Omitting asylum population.

Besides the amount diverted by the water supplies, large quantities of water are diverted from the lower part of the watershed by the system of sewers in Waltham, Newton, West Roxbury, Dedham and Wellesley. The only site where it would be possible to construct a large storage reservoir within the Charles River watershed is in the area which includes the Medfield Meadows, so called, extending from South Natick to the neighborhood of Medway. The area of the watershed tributary to a reservoir in this location would be about 156.3 sq. mi.

The reservoir would hold about 9 000 000 000 gal. with an average depth of 9 ft., or 18 000 000 000 gal., with a 12-foot depth, and might furnish a safe yield of from 63 000 000 to 93 000 000 gal. per day according to the height of the dam.

Obviously the diversion of all of the water from the drainage area above this proposed dam would greatly damage the water supplies along the river below and the requirement that one-third of the flow of the river must be allowed to flow through Mother Brook introduces another complication. The necessity of maintaining proper sanitary conditions in the river below, and especially in the Charles River basin, is still another requirement, besides the need of allowing enough water to run for the use of the factories and mills along the stream. Certainly any taking of water from the upper part of this valley now would have to be a limited one and, taken in connection with the cost of the proposed reservoir, together with the cost of properly purifying the water and conveying it to the district, would unquestionably be excessive in view of the quantity of water likely to be obtained.

Among other near-by rivers which may be considered as possible sources of additional water supply are the Shawsheen, the Ipswich and the Merrimack. The Shawsheen was considered many years ago and rejected as impracticable. The Ipswich River has already been divided up between the cities of Lynn, Peabody, Salem and Beverly and the towns of Danvers, Saugus, Reading and Middleton, and the question has been raised as to whether it may not be a proper source for some of the municipalities in the Merrimack valley. With the highest practicable development a very large part of the supply from this source would be required for the cities and towns in the densely populated county of Essex, and little would remain for the use of the Metropolitan Water District. The use of the Merrimack River as a source of water supply for the Metropolitan District was carefully investigated by the State Board of Health in 1895 and rejected for reasons which proved satisfactory to the Legislature of that day. Far more serious objections would arise to any proposition to use that river as a source of water supply for the Metropolitan Water District at the present time, even assuming that the inhabitants of the district would be willing to use so polluted a water for drinking even with the best system of purification that it would be practicable to devise. The use of the water of this river for water supply purposes would require a thorough system of filtration and would make necessary the pumping of all of the water drawn therefrom for the supply of the district. Furthermore, the use of that source would eventually not only reduce materially the amount of water available for power and industrial uses at Lowell and Lawrence, which would have to be replaced by power from other sources, but would also involve the installation of power plants for pumping the water required by the district and the use of an ever increasing quantity of fuel for the purpose or the purchase of power which would otherwise be available for other uses. The taking of this water would also involve serious interference with the flow of water available for maintaining proper sanitary conditions in this river which has already been the source of complaint below the proposed point of diversion. The use of this river was rejected for excellent reasons

many years ago and its use would obviously be more objectionable today. The waters of many rivers in the eastern part of the state like the Aberjona River and its impounding reservoir, the Upper Mystic Lake, are unfit for domestic use. In this class are the Neponset and Blackstone rivers and the Nashua River and its North Branch, while the Squannacook — which is the only large branch of the Nashua suitable for water supply — would not furnish sufficient water to pay for its development for the Metropolitan Water District.

There are no practicable sites for storage reservoirs on the Concord and Sudbury rivers, and of the large natural lakes and ponds which might otherwise be available, Lake Winnepesaukee is in New Hampshire and Assawompsett and its tributary ponds are used, and will be needed, by the municipalities of Bristol County.

The Assabet River.

In the report of the State Board of Health in 1895 containing the plan for the present Metropolitan water supply, certain tributaries of the Assabet River are mentioned for use in the first probable extension to the Metropolitan water supply system when an additional supply should become necessary. The investigations at that time indicated that the waters of several small streams in the upper part of the Assabet River watershed, through which the Wachusett Aqueduct passes in its course to the Sudbury Reservoir, could be utilized for supplementing the Metropolitan water supply by diverting them into the aqueduct through some six separate connections. The watershed of one of these streams, however, is used as a source of water supply for the town of Northborough and that of another which drains an area along the Boston and Albany Railroad above Westborough has become much more populous than was the case years ago. Furthermore, the sewage disposal works of the town of Westborough are located in this valley just below the proposed point of diversion, and if the flow of this watershed were to be diverted as proposed little water would be left in the river during the drier part of the year to dilute the effluent from those works. There has been much litigation over the condition of this river below the sewage disposal works in past years and under the circumstances the diversion of water from this tributary at the present time is inadvisable. Omitting these areas, including one other small area which would naturally be grouped with them, the total remaining watershed is 21.9 sq. mi., and if all of the water possible should be diverted from this area for the use of the Metropolitan Water District, the additional safe yield thereby obtained would not exceed about 17 000 000 gal. per day.

The Assabet River watershed below the areas drained by these streams contains several large towns in which are located important factories and mills, some of which use large quantities of water in their processes; while one, the woolen mills at Maynard, uses at times nearly the whole dry-

weather flow of the river for such purposes. Furthermore, in addition to the effluent of the sewage disposal works of the town of Westborough, that of the town of Hudson is also discharged into the river; and similar disposal is made of the effluent from small sewage disposal works in the town of Maynard, which flows into one of the tributaries of the river. There are also works for treating manufacturing wastes at some of the mills, the effluent of which is discharged into the stream. This river has been the source of much complaint in past years on account of pollution by sewage and manufacturing waste and considerable litigation has resulted therefrom. Its condition finally became so objectionable that the Legislature passed a stringent law designed to prevent its further pollution. The conditions now existing in this valley are such that if the whole flow of water from the portion of its watershed in question were diverted from the river the condition of the stream would no doubt become more objectionable. Under the circumstances the damages which would be likely to result from the taking of the entire flow of these streams, in addition to the damage to water power alone, would be likely to be large, and it is not at all probable that so complete a taking of water would or should be authorized by the Legislature at the present time. The amount of water which could be obtained from this source would consequently depend upon the limit of taking which might be imposed by the Legislature. Limited takings are common enough in the legislation of Massachusetts and the advisability as a general policy of limiting the quantity of water that may be diverted from most of the watersheds of the State, sufficiently to prevent any serious diminution of their flow in the drier part of the year, will hardly be questioned by anyone having a thorough knowledge of the conditions which exist in most of the river valleys. If the district should be authorized to take all of the flow of these streams in excess of 0.35 of a c.f.p.s. per square mile of watershed, or about 225 000 gal. per square mile per day, which is the approximate limit of taking in the case of the Ipswich River, but without other limit as to the quantity or time of diversion, the safe yield obtainable from the use of these streams in the Assabet River watershed would be about 11 000 000 gal. per day. This amount would be sufficient for the needs of the district for no more than about three years after the capacity of the present sources had been reached and the amount obtainable would hardly pay for the trouble and expense of the taking. Furthermore, the taking might be even further restricted and in that case the amount of water available would be less. With conditions as they are it has seemed inadvisable to recommend the taking of any water from the Assabet River, though it may become necessary to use water from some portions of this watershed in case an emergency should arise since water can be diverted from these streams more readily probably than from any other available source.

The Ware and Swift Rivers.

In the report of the State Board of Health upon a Metropolitan water supply in 1895 it was recommended that a second source of considerable size could be tapped when the Wachusett Reservoir supply on the Nashua River could be augmented by building a tunnel to Coldbrook on the Ware River and diverting the water from a drainage area of about 100 sq. mi. It was further suggested in that report that later on a reservoir could be built in the Swift River valley, and the water also delivered to Wachusett Reservoir by gravity through an extension of the tunnel from Coldbrook to the Swift River. Reference was also made to the possibility of using later as supplementary supplies water from the Deerfield and Westfield rivers in the extreme western part of the state.

When the recent investigation was undertaken great changes had taken place in the conditions affecting the use of these rivers as sources of water supply for the Metropolitan Water District. The population in the rural areas throughout the State has declined steadily for many years while, on the other hand, the industries along many of the river valleys have grown and the population has grown with them, and the prosperity of these valleys has become almost wholly dependent upon the prosperity of the industries along the rivers. In the Ware River watershed little change of importance has taken place in the neighborhood of Coldbrook or above it, in the region from which it was proposed in 1895 to take an additional water supply for the Metropolitan Water District; but in the valley of the Ware River below Coldbrook, and in that of the Chicopee River of which the Ware is one of the principal tributaries, the industries have become much more important than in 1895. And the water is used not only for power but for various manufacturing processes in the mills and factories along the stream. Furthermore the dry weather flow of the rivers is depended upon for the effective dilution of the sewage and manufacturing wastes which after more or less purification in some cases, and in others none at all, are discharged directly into the stream. The total drainage area of the Ware River at its mouth is about 221 sq. mi., and if all of the water were diverted from 100 sq. mi. above Coldbrook, the flow of the river would be diminished nearly one-half in the neighborhood of its mouth and in an increasing proportion from point to point farther up stream, until in the vicinity of the proposed dam there would be little or no flow after the full supply of this source came to be required by the district, except such amounts as might be wasted at times of high freshets, usually in the early spring. There is no question that, in order to avoid excessive costs and damages, and especially to avoid permanent injury to the prosperity of this valley, it will be necessary to limit the amount of water to be diverted from it, especially in the drier part of the year. Since it was deemed inadvisable to divert any part of the Assabet River watershed for the permanent use of the Metropolitan Water District, and since only a limited taking of water from the Ware River is

likely to be authorized, the question of obtaining a material addition to the water supply of the Metropolitan Water District required the consideration of other additional sources.

The source suggested by the State Board of Health in 1895 for the next extension beyond the Ware River was the Swift River, upon which the preliminary studies indicated that a very large storage reservoir could be constructed by means of a dam above West Ware about 8 miles from the mouth of the river at such a height as to make practicable the delivery of nearly all its storage into Wachusett Reservoir by gravity. While the effect of the diversion of the whole flow of the Swift River might be comparatively small, so far as the remaining drainage of that river below the proposed dam is concerned, the effect upon the Chicopee valley below, of which the Swift River is one of the three principal tributaries, would be most important, and in this case again the taking of the whole flow of the stream was deemed inadvisable, on account of the large damages that might result and the possible injury to the prosperity of this important industrial district.

While the taking of the whole flow of the Swift River would be objectionable, the possibilities of the great reservoir which might be constructed in the Swift River valley, afforded by the circumstances of its location, presented an opportunity rarely offered to reverse the usual practice; and, instead of taking the entire flow or even the larger part of the flow of any one or two streams, to take the freshet flows of a large area by combining a number of streams together, and thus avoid any interference whatever with flows which are materially less than the average and which prevail ordinarily for more than half the year; that is, to take from the top of the time flow curve instead of the bottom.

Conservation of Flood Waters by Diverting only the Higher Flows from Large Areas.

The distribution of the rainfall in New England is such that the greater part of the water yielded by the rainfall and melting snows passes off in the streams in the winter and spring and, while the river valleys are ordinarily inundated for a few weeks in the latter season, the streams usually shrink to comparatively small dimensions for many months in the summer and fall. The Swift and Ware rivers and the other rivers in that region are no exceptions to this rule. Measurements of the Swift River, at a measuring station maintained by the U. S. Geological Survey in coöperation with the State of Massachusetts for several years at West Ware, a short distance below the proposed main dam in this valley, have shown a maximum flow in the period extending from August 1912 to December 1921 as high as 8 000 000 gal. per square mile per day and a minimum below 80 000 gal. Wider variations would no doubt have been shown if records of a longer period were available. There are ordinarily many weeks in the winter and

spring, and also periods in the summer and autumn in some years, when the flow of water exceeds the capacity of the wheels in most of the power plants on the Swift and Ware rivers and on the Chicopee River below them; and water runs to waste over all of the dams on these streams. On the other hand, in the summer and autumn the flow usually falls below the capacity of the wheels, and a part of the power necessary for operating machinery in the factories and mills must in many cases be obtained from other sources or from auxiliary steam plants maintained for the purpose.

The diversion of the water of the higher flows into an adequate storage reservoir, would diminish the freshets, which interfere at times with the operation of power plants and cause injury in other ways. The storage afforded by the proposed reservoir in the Swift River valley would be so great that with that reservoir in use it would be practicable so to regulate the discharge into the Swift River that instead of a variation of flow ranging from 80 000 to 8 000 000 gal. per square mile per day, a nearly uniform quantity of water could be discharged to the mills below at all times, in years of excessive rainfall and in years of drought, with comparatively little waste in proportion to the whole quantity used.

If a supply should be obtained for the Metropolitan Water District by taking the entire flow of the Ware and Swift rivers for the use of the district, the damage done to the mill powers and other interests in the valleys below might not be serious in the beginning but it would have to be paid for, though a part of the water would be available for many years for the use of its former owners. On the other hand, by taking advantage of the storage afforded by the great reservoir in the Swift River valley, and retaining therein only the higher flows above the quantities of water which are required by the majority of the industrial power plants, the water flowing in periods of excess could be diverted for water supply uses and the remaining water allowed to flow past the dams in varying quantities, as it does to-day, or in such quantities and at such times as might be mutually agreed to be to the best advantage of those who use the water for power. In this way the damages to water powers could be greatly reduced, the variations in the flow of the river could be regulated, and injury to the prosperity of the valleys prevented.

Utilizing the Flow of Other Rivers in Connection with that of the Swift and Ware.

Following out the idea of combining the flows of several rivers and taking only the higher flows, which are now of little or no value and usually a detriment to the valleys which the rivers drain, studies have been made of the other rivers from which water might be diverted into a proposed reservoir in the Swift River Valley. The results of these studies indicate that, in addition to the waters of the Ware River and of parts of the watershed of the Lower Ware, so called, between Coldbrook and Gilbertville,

water could be diverted into the proposed reservoir from large parts of the watersheds of the Millers, the Quaboag, the Deerfield and the Westfield rivers. In fact, the total drainage area which could ultimately be made tributary to this reservoir amounts to more than 1 200 sq. mi. and is equivalent to about one-sixth the total area of the State.

With the amount appropriated for the investigation it was possible to make an adequate preliminary study of all of the watersheds which might be utilized in connection with this plan. The nearest of the rivers to the proposed reservoir, aside from the Ware, are the Quaboag and the Millers rivers, and of these the Millers would apparently be the more favorable for use since it has a larger watershed than the Quaboag and requires a shorter conduit for connection with the proposed Swift River Reservoir. The Millers River was not carefully considered as a source of water supply at the time of the previous investigation because of the fact that one or two towns of considerable population are located within its watershed and might cause objectionable pollution of the water. Further consideration of the possible use of this watershed shows that the larger of the towns is but little greater in size than the largest municipality within the present Metropolitan watershed area, and if the largest of the towns in the latter watershed, which is situated at the head of the Sudbury Reservoir can be so dealt with as to prevent its being a menace to the Metropolitan water supply at the present time, it seemed possible that the drainage from the towns on the Millers River might also be cared for satisfactorily,— in view of the circumstances,— if it should be desirable to use that stream for water supply purposes. Accordingly, studies were made to determine the practicability of combining the freshet flows of the Millers River with those of the Ware and Swift in the Swift River Reservoir. The results of these studies show that by combining the flows of the Ware, Swift and Millers rivers, it will be necessary, in order to secure an additional water supply of 200 000 000 gal. per day for the Metropolitan Water District, to divert only those flows which are in excess of 1.2 c.f.p.s. per square mile of watershed or the flows in excess of about 775 000 gal. per square mile per day. Such an additional supply would meet the requirements of the Metropolitan Water District and the municipalities which may be dependent thereon for water for a very long time in the future.

In this study a considerable portion of the flow of the Lower Ware River, so called, that is, that portion of the watershed of the Ware River, below Coldbrook, has been included. While there have been no material changes in the valley of the Ware River above Coldbrook, a region which is very sparsely populated, the conditions in the valley of the river below Coldbrook have changed materially and the plan of diverting water directly from the Ware River in this part of its watershed would be impracticable at the present time on account of the pollution of the river; but it will be feasible to divert the freshet flows of the more important streams in this watershed having an aggregate area of at least 20 square miles, and probably

much more, by diverting these flows directly into the shafts of the proposed tunnel from the Swift River to the Wachusett Reservoir at points where the tunnel passes beneath these areas, whenever it may be deemed desirable to do so.

Cost of Utilizing the Freshet Flows as Compared with More Complete Taking of Smaller Watersheds.

Having determined that an adequate water supply for the Metropolitan district, and the cities and towns likely to be dependent thereon for water for many years in the future, could be obtained by the development of such a plan as has been described, the necessary studies were made to determine the advantages and comparative cost of developing a water supply in this way, as compared with the cost of the more complete takings of a smaller area of watershed common in an earlier day. In making these estimates, it has been assumed that the limit of the taking of water from these streams would be placed higher than in the case of the Ipswich River, where the maximum taking was limited to flows in excess of about 230 000 gal. per square mile of watershed per day. The conditions in the valley of the Ware River, and of the Chicopee River below the junction with the Ware River, are very different from those along the Ipswich River below the lowest point of taking on that stream. The Ipswich River valley below these takings is very sparsely populated with no factories or mills or villages of any notable size within it until the river reaches Ipswich, where it discharges into the sea. In populous valleys like those of the Ware and Chicopee rivers, a limit should necessarily be placed much higher than in the case of the Ipswich River, if serious injury to the prosperity of these valleys is to be avoided. It has been assumed in these estimates that the limit might be about twice as high as in the case of the Ipswich River; that is, that the takings in the valleys of the Ware and Swift rivers might be limited to flows in excess of about 500 000 gal. per square mile per day, or about 0.8 of a c.f.p.s. per square mile. With this limitation the estimated cost of a water supply to the Metropolitan Water District, from the Ware and Swift rivers combined, was found to be practically the same as the estimated cost of a water supply from the Ware, Swift and Millers rivers combined with a taking in excess of 775 000 gal. per square mile per day. Since there would be much less interference with the flow of the streams in the case of this latter taking, there is no question as to which method is the better for the State to adopt.

As a result of these investigations the plan recommended for obtaining an additional water supply for the Metropolitan Water District is the construction of the proposed reservoir in the Swift River valley, the diversion of the higher flows of certain portions of the Millers and Ware rivers, into the Swift River Reservoir and the construction of a tunnel to convey the water to Wachusett Reservoir, and thence to the district. This scheme

lends itself remarkably well to the growing needs of the district and of the other communities requiring water in the eastern part of the State. With the present rate of growth and increase in the use of water, an additional water supply will be needed by the district soon after 1928, the exact time depending upon the uncertain factor of the rainfall in the period when the consumption of water in the district reaches the safe capacity of the works. It will be practicable if work is begun without delay to construct the first half of the tunnel as far as Coldbrook within the next 6 years, and thus make available part of the freshet flows of the Ware River with which the safe yield of the Metropolitan sources would be increased by about 33 000 000 gal. per day, assuming that the taking of water from the watershed of the Ware River above Coldbrook would be limited to quantities in excess of 1.2 c.f.p.s. per square mile of watershed. The plan also makes possible an additional water supply for the city of Worcester. It is possible to obtain water for Worcester from one of the tributaries of the Quinepoxet River, though this is likely to be objected to by the Metropolitan Water District, while a more favorable plan is that of pumping directly from Wachusett Reservoir for the supply of the city of Worcester as was done in an emergency some 10 years or more ago. Under the plan now proposed the tunnel would pass beneath the upper end of one of the tributaries of the new Pine Hill Reservoir, and water can be pumped from the tunnel into this tributary for the water supply of the city of Worcester if desired.

While the safe yield of the Metropolitan sources would be increased 33 000 000 gal. with the completion of the first section of the tunnel, the safe yield of the Ware River watershed above Coldbrook would be increased to some 47 000 000 gal. per day with the completion of the Swift River Reservoir and a tunnel thereto, under the same taking, since the extension of the tunnel would make it practicable to store a part of the water in the reservoir on the Swift River which would go to waste while only the lower or Ware-Wachusett Section was in use.

There is no doubt that the diversion of the freshet flows of the Quaboag River into the Swift River Reservoir in the beginning would make practicable a limit of taking somewhat higher than suggested in the report presented. The question whether it would be advantageous to make this diversion in the beginning, or to divert the freshet flows from some of the smaller tributaries of the Ware River below Coldbrook requires further consideration and can be postponed to a later time.

The Swift River Reservoir.

The Swift River is the westernmost of the three streams which unite in the neighborhood of the village of Three Rivers in the town of Palmer and form the Chicopee River. These three streams with their drainage areas are as follows:

Swift River	213 square miles
Ware River	221 square miles
Quaboag River	210 square miles

It is practicable to create a reservoir in the valley of the Swift River which would have about half the area of Lake Winnepesaukee by constructing a dam across the main river at the boundary line between Enfield and Ware and a secondary dam or dike in the Beaver Brook valley about 3 miles northeast of the main dam.

The Main Dam and Dike.

At the site of the proposed main dam the bed rock is overlaid by a deep deposit of gravel and sand, porous and water-bearing, and a form of construction carried to bed rock will be necessary as the overlying material cannot be made impervious to water. The proximity of great quantities of suitable material indicates that an earthen dam with a core wall of impervious material will be the most appropriate form of construction under the circumstances. An excellent location for a spillway and overflow channel is found beyond the rocky hill at the westerly end of the dam where the waste water will be returned to the river well below the dam and safe from possible injury to the dam or other structures. The conditions for constructing a dike at the divide between the Swift and Ware rivers are not satisfactory, but a suitable site for the dike is found in the valley of Beaver Brook about a mile south of the divide where the conditions are similar to those at the site of the main dam, and though its length will be less, the form of construction proposed is similar.

Some of the principal dimensions of the proposed structures are shown in the following table.

Dimensions of Main Dam.

Elevation of flow line above present surface of river	147 ft.
Elevation of flow line above bottom of rock gorge	253 ft.
Width of gorge at flow line	2 700 ft.
Height of top of dam above flow line	18 ft.
Width of dam at top roadway	36 ft.

Dimensions of Beaver Brook Dike.

Height of flow line above present brook	115 ft.
Height of flow line above bottom of rock gorge	260 ft.
Length of dike at flow line	2 150 ft.
Height of top of dike above flow line	18 ft.
Width of dike at top roadway	36 ft.

The upstream slopes of both dam and dike would be somewhat less steep than 1 to 3 and the downstream slopes somewhat less steep than 1 to 2.5.

Character of the Proposed Reservoir Area.

The reservoir would contain a number of semi-mountainous islands, rocky and for the most part covered with forest at the present time; and it would be necessary for the protection of the water to acquire all of the islands, together with lands about the margin, in order to keep them

free from population and from uses which might be objectionable in the neighborhood of a reservoir used as a source of public water supply.

The dimensions of the reservoir, tributary drainage area and other facts concerning it are given in the following table:

Area of water surface	39	sq. mi.
Area of watershed, Swift River	186	sq. mi.
Area of watershed divertible from Ware River	130	sq. mi.
Area of watershed divertible from Millers River	*220	sq. mi.
Total capacity	410 000 000 000	gals.
Length	17	mi.
Maximum width	4	mi.
Total length of shore line not including islands	86	mi.
Maximum depth	150	ft.
Average depth	51	ft.
Length of railroads flooded	15.9	mi.
Length of highways flooded	106	mi.

Population on the Reservoir Area.

In the construction of the proposed reservoir it would be necessary to remove practically the entire population of three towns and a considerable population would be affected in three others, while the habitations of a few people in five other towns would also probably have to be acquired. The towns affected, together with their population in national census years since 1880, are given in the following table:

Town.	1880.	1890.	1900.	1910.	1920.	Estimated Population in 1920.	
						Within Proposed Swift R. Res.	Within Area of all Probable Takings.
Enfield	1 043	952	1 036	874	790	694	790
Dana	736	700	790	736	599	331	378
New Salem	869	856	807	639	512	60	83
Pelham	614	486	462	467	503	20	36
Greenwich	633	526	491	452	399	393	399
Prescott	460	376	380	320	236	63	236
Hardwick**	....	....	....	....	....	30	65
Belchertown**	....	....	....	....	....	4	26
Shutesbury**	....	....	....	....	....	3	17
Petersham**	....	....	....	....	....	7	10
Ware**	....	....	....	....	....	0	8
Totals	4 355	3 896	3 966	3 488	3 039	1 605	2 048

The foregoing table indicates that the habitations of somewhat more than 2 000 persons would have to be removed in the construction of the proposed reservoir as against 1 711 in the case of the Wachusett Reservoir.

*This area includes certain small watersheds from which the water supplies of Ashburnham, Gardner, Winchendon and Athol are taken.

** Population of these towns very slightly affected.

The assessed value of real estate in the six towns most seriously affected in the years 1901, 1914 and 1920 is shown in the following table:

Town	1901	1914	1920
Enfield	$414 890	$470 680	$472 440
Dana	248 957	344 441	413 395
New Salem	246 760	328 600	409 910
Pelham	164 799	338 903	431 165
Greenwich	175 915	210 500	295 345
Prescott	139 012	171 322	176 905
Totals	$1 390 333	$1 864 446	$2 199 160

An examination of the area to be flowed shows that it contains in all 1 040 buildings besides 18 abandoned and 66 in ruins or with their foundations only in evidence. The character of these buildings is shown in the following table:

Mill structures	14	Houses, occupied	463
Stores in use	38	Houses, vacant	30
Churches	6	Barns, in use	381
Schoolhouses	13	Barns, vacant	18
Other public buildings	2	Camps and summer cottages	61
Railroad stations, Freight houses, etc.	14	Total	1 040

The total number of occupied dwelling houses as shown by the above table is 463, or about 12 per square mile, as compared with 224, or about 35 per square mile, on the area taken for the Wachusett Reservoir.

A survey has also been made to determine the character of the areas to be flooded and the present uses of the land. These statistics are shown in the following table:

Orchards	51 acres
Pasture and open land	2 118 acres
Swamp and meadow	2 338 acres
Scrub and young growth	7 889 acres
Timber land	6 845 acres
Water surfaces	1 233 acres
Cemeteries	11 acres
Unclassified lands such as village and cultivated land, highways and railroads	4 385 acres
Total	24 870 acres

Treatment of the Reservoir Area.

The greater part of lands that will be covered by the proposed reservoir are at present sandy plains covered with brush or wood and having a very thin surface layer of loam. Swamps containing peat are exceedingly rare, the aggregate area of such deposits amounting apparently to less than 700 acres. A large part of the swamp and meadow land is low ground between the main stream and the uplands, kept in a swampy condition in many cases by the ground water percolating from the gravelly lands adjacent. The preparation of this great area for reservoir purposes by the removal of all vegetation and of all surface soil besides would be impracticable on account of the excessive cost, and is unnecessary in the existing circumstances. The land should be cleared of bushes and trees and all organic matter destroyed so far as practicable. It is probable, moreover, that over large areas even the surface soil can be reduced largely to ashes, so that by this process the small amount of organic matter that remains is likely to have little permanent effect upon the quality of the water of this great basin. In the earlier years, after the area is first flowed, the water will doubtless have a noticeable color, and a considerable quantity of organic matter will be taken up by contact with the material in the bottom of the reservoir, but this condition is unlikely to affect the water materially beyond the first few years. It will take several years to fill the reservoir, and during much of that time there is no doubt that water of such quality can be obtained from it that after subsequent storage in Wachusett Reservoir the quality of the water of the latter source would not be materially affected thereby, since the water need be drawn in the earlier years from the Swift River Reservoir only at times when the quality is at its best. The capacity of the proposed reservoir is such, in proportion to the size of its watershed, that the water stored there will eventually become thoroughly bleached and probably nearly or quite colorless, and while it may be affected at times in the earlier years by growths of organisms and the objectionable tastes and odors which result therefrom, the use of the reservoir at such times can be avoided.

With the increasing demand for water of the best quality, it is possible that most surface waters, no matter how free from probable danger of pollution, will be filtered before delivery to consumers, and this may sooner or later be the case with water supplied from the Wachusett system, but such a demand seems unlikely to arise for many years.

If it should ever be found desirable to improve the quality of the water of the proposed Swift River Reservoir by filtration before discharging it into the Wachusett Reservoir, rather than to filter all of the water supplied from the latter source, it would be practicable to filter it on lands in Oakdale adjacent to Wachusett Reservoir. But it is not probable that the water of the proposed Swift River Reservoir would differ materially from that of the Wachusett Reservoir after the first few years.

Tunnel from the Proposed Swift River Reservoir to Wachusett Reservoir.

The divide between the Wachusett Reservoir and the watersheds of the Ware and other rivers to the west rises to a height of over 1 000 feet above sea level, a height which it maintains generally for many miles from the northerly nearly to the southerly boundary of the State. This high divide must be pierced by a tunnel in order to bring water from the Ware or Swift rivers into the Wachusett Reservoir, and this connecting link between the present and the proposed supplies will be a most important item of construction.

The tunnel as designed will leave the Swift River Reservoir about half a mile south of East Pond at the foot of a steep rocky hill rising some 400 feet above the floor of the Swift River valley east of the village of Greenwich, and will run northeasterly to the neighborhood of Coldbrook in the Ware River valley, whence it will turn to the east and follow an easterly course to the Wachusett Reservoir.

The tunnel from the Swift River valley to the Wachusett Reservoir will pass so close to Coldbrook on the Ware River that the slight change in alignment made necessary to provide for the diversion of the water of this river directly into one of the tunnel shafts would have very little effect on the length of the line. Since the control works would be located at the Wachusett end of the tunnel, the tunnel itself would become in effect a part of the reservoir, and floods from the Ware River would flow back through the tunnel and be stored in the Swift River Reservoir whenever necessary.

As previously stated, it would be possible, whenever desirable, to divert the flood flows from several small watersheds, having an aggregate area of 19 square miles or more, tributary to the Ware River below Coldbrook into the tunnel at various shaft heads. These connections are not included in the preliminary estimates, however, because the expense of their construction would probably not be justified for many years.

The total length of the proposed tunnel to the Swift River Reservoir is about 25.1 miles. It would be located in rock, and the surface indications are favorable to construction by methods known and tried in many similar cases, but as many of the construction shafts must be deep, it is desirable, for the sake of economy, that they should be spaced at intervals of 3 or 4 miles, and probably at least four years will be required for actual construction to get the first water from the Ware River at Coldbrook into the Wachusett Reservoir. Delay in beginning the construction of this tunnel, which would require more rapid work, would mean a serious addition to the cost.

The cost of such a tunnel and the time required for its construction make it advisable to build it large enough to carry as large a quantity of water as can probably be utilized from the Swift River Reservoir, developed

as ultimately proposed, since the larger tunnel will cost less in proportion to its size than a small one. Accordingly, for the purpose of estimating the cost, this diameter has been taken at 12 feet 9 inches. With this diameter, in a series of dry years, which might cause the main reservoir to be drawn down 55 feet, or to about elevation 474, there would still remain sufficient head on the tunnel to enable it to carry 500 000 000 gal. per day. The lowest gate sill in the intake gatehouse has been designed at elevation 435, which is about the floor of the main portion of the Swift River valley. This will allow an initial supply to be obtained the first year that the storage of water is begun, and would make it practicable to draw nearly the maximum storage of the proposed Swift River Reservoir into the Wachusett Reservoir. At its lower end the invert of the tunnel as proposed would be at grade 370, the outlet of the tunnel being at Oakdale at the upper end of the Wachusett Reservoir.

Aqueduct for Millers River Diversion.

Reference has already been made to the proposed diversion of water from the Millers River. This would be accomplished by a tunnel and aqueduct leading from diversion works just above Athol to Eagleville Pond, an existing millpond on the Millers River watershed just north of the divide between the Swift and Millers River drainage area, and thence by a channel cut through the divide from the southerly end of that pond into the Swift River Reservoir. For the purposes of this estimate the tunnel and aqueduct to Eagleville Pond is designed at about 11.5 feet in diameter, and would be capable of diverting flows in excess of the normal undiverted flow of the river up to and including 5 cubic feet per second per square mile. The watershed of the Millers River above the proposed point of diversion is, as already stated, 201 square miles, but the flow would be reduced slightly by the diversion of water for certain water supplies and by the removal of the effluent from the sewage disposal works in Gardner and Templeton, as well as those which may be built in Winchendon. The amount of these diversions from the higher flows of the river is small.

Estimates of Cost.

In making estimates of the cost of the proposed works difficulty was encountered on account of the constant changes in prices of labor and commodities in recent years. It was decided to base the estimates wholly upon pre-war prices, and this plan has been followed throughout. The following table shows also an estimate of the probable cost of the works on a pre-war basis plus an addition of 30 per cent to allow for conditions which may exist if the bulk of these works should be constructed within the next ten to fifteen years. In making the estimates experience in similar construction on the metropolitan water supply in recent years, on similar work now under construction for the city of Providence, and especially on

the water supply of the city of New York, has been utilized, as well as that of other cities. In every construction item an allowance of about 22 per cent has been made for unforeseen contingencies, all preliminary surveys and designs and the preparation of contracts, as well as administration, general supervision and engineering during construction.

Summary of Cost Estimates.

		Construction Cost and Overhead (Pre-War Basis).	Probable Cost in 1924-35 (Pre-War Basis +30 Per Cent.)
Main dam at West Ware station:			
Main embankment	$7 124 000		
Diversion tunnel and control works	1 201 900		
Spillway and flood channel	251 700		
		$8 577 600	$11 150 880
Beaver Brook dike:			
Main embankment	6 529 000		
West dike	85 000		
		6 614 000	8 598 200
Main storage reservoir in Swift River valley:			
Clearing, grubbing and fencing			
Relocation and reconstruction of highways, 47 miles			
Relocation of railroad, 21½ miles		5 064 300	6 583 590
Relocation of cemeteries			
Relocation of transmission lines			
Sanitation and forestry			
Eagleville Reservoir diversion:			
Raising Eagleville dam	44 700		
New channel via Hacker Pond	108 400		
		153 100	199 030
Millers River diversion:			
Diversion dam and intake	159 400		
Aqueduct to Eagleville Reservoir	1 173 500		
Gardner and Winchendon sewer	729 400		
		2 062 300	2 680 990
Aqueduct to Wachusett Reservoir:			
Tunnel and shafts	17 457 100		
Intakes to aqueduct	376 000		
Wachusett terminal	339 400		
		18 172 500	23 624 250
Total Construction		$40 643 800	$52 836 940
Real estate, rights of way, depreciation, business damages, diversion damages and water rights of mills and factories below points of diversion			7 109 600
Total			$59 946 540

Estimated Cost of Proposed Extension to the Ware River.

The first addition to the metropolitan water supply under the plan herein proposed, which will give an additional safe yield of about 33 000-000 gallons a day, is the taking of the flow of the Ware River at Coldbrook in excess of 1.2 cubic feet per second per square mile of watershed. This involves the construction of the proposed tunnel from a shaft at the Quinepoxet River, a tributary of the Wachusett Reservoir, as far as a shaft at the Ware River in Coldbrook, including the necessary terminal works and diversion spillway at the Quinepoxet shaft near the Wachusett end.

The estimated cost of this portion of the works is as follows. This estimate does not include the simultaneous cost of any preliminary work on the further extension to the Swift River Reservoir, although this extension would need to be begun before the tunnel to the Ware is completed.

Summary of Cost Estimates.

First Extension to the Ware River at Coldbrook.

	Construction Cost and Overhead (Pre-War Basis).	Probable Cost in 1924–27 (Pre-War Basis + 30 Per Cent)
Tunnels and shafts	$8 368 600	$10 879 180
Intakes to aqueduct	297 000	386 100
Total Construction	8 665 600	11 265 280
Real estate, rights of way, diversion damages and water rights, mills and factories below the point of diversion		778 100
Total		$12 043 380

Summary and Conclusions.

If the Metropolitan Water District continues to grow it will need an additional water supply. If it grows at a somewhat less rate than before the war and the consumption of water per capita does not increase, the safe yield of the present supplies will probably be adequate until about 1930, but if the consumption per capita continues to increase, as has been the case in the district in recent years and in practically every city in the northern part of the United States, notwithstanding the general metering of the services, the consumption of water will equal the safe yield of the sources of supply by 1928. The city of Worcester, if its past rate of growth continues, will also need a new water supply in 1928; and the most favorable source from which that city can obtain a supply under present conditions is the Wachusett Reservoir or its watershed. There are other cities and towns adjacent to the Metropolitan Water District which are now using nearly or quite all of the water which their sources are capable of yielding in years of low rainfall and which will inevitably require a water supply from the district with the coming of the next dry period. Such periods

have occurred at irregular intervals averaging about five or six times in a century, the last one in recent years ending in 1911. Ten years more, or even a longer time, may yet pass before another dry period begins, or it may begin in the present year. Just at the present time with the experience of the heavy rainfalls of recent years, especially in the summer season, it is exceedingly difficult to convince anyone unfamiliar with water supply problems that the time will come when the sources of water supply now in use will prove inadequate. Water has wasted in practically every recent year in great abundance over the dams of all of the reservoirs in such quantities as to make it appear that all that is required in order to obtain an increased water supply is to add a few feet to the top of the dam.

But the increase in the yield of a watershed obtainable by enlarging the storage is by no means directly proportional to such enlargement. While the yield of a given watershed with a storage of 25 000 000 gal. per square mile may be nearly doubled when the storage is increased to 50 000 000 gal. per square mile, on the contrary doubling the storage capacity, when the storage is equivalent to 200 000 000 gal. per square mile, in ordinary cases only increases the safe yield from 12 to 15 per cent. On the Metropolitan watersheds the storage is highly developed, especially in the case of the Wachusett Reservoir, which comprises 80 per cent of the entire storage of the system and upon which the storage developed is over 600 000 000 gal. per square mile of watershed.

It is impossible with such a distribution of rainfall as obtains in New England so to adjust the draft from a reservoir like the Wachusett as to make available all of the water which the watershed yields; for if the draft were adjusted to insure the use of all of the flow in periods of maximum rainfall, that draft would exhaust the storage in years of drought. The draft from any water system must be so arranged that the supply will be adequate in periods of drought, and in consequence there will inevitably be a waste in periods of high rainfall. Furthermore, reservoirs are not built for immediate needs and cannot commonly be built from year to year to supply growing wants; but new construction generally allows for increasing requirements for a considerable period of years; and, in consequence, in the earlier years of the use of a water supply reservoir, large quantities of water may be wasted because the draft has not reached the safe capacity of the source of supply. But as the draft becomes equal to or exceeds the safe yield of the source, years of low rainfall quickly demonstrate its inadequacy and unless provision is made in advance, shortgage inevitably results.

In the case of the water supply of the Metropolitan Water District, the consumption of water already equals the safe yield of the Wachusett and northern Sudbury sources, and further increase in the needs of the district must be supplied from the old southern Sudbury and Cochituate sources which have a combined capacity of perhaps 30 000 000 gal. per day. These sources were used regularly in the past and in the last very dry year,

1911, when Wachusett Reservoir was drawn to the lowest level thus far recorded, 40 per cent. of the supply of the district was obtained from the Sudbury and Cochituate works, chiefly the older Sudbury Reservoir and later Cochituate. The waters of these latter sources, to-day, are unsafe and objectionable for water supply purposes unless properly filtered. Filters are not yet available for the treatment of these waters; but unless provided and used before Wachusett Reservoir becomes materially depleted at the beginning of a dry period, the safe yield of the Metropolitan sources will be much less in such a period than shown by the figures presented. The calculations are based on the records of yield in the dry period which practically closed in 1911, — a period which was not as dry as others of record. If the water supply of the Metropolitan Water District is to be maintained to meet conditions of drought such as have occurred in the past, an additional supply should be available by 1928 or 1930, since the district is likely then to be using all of the water which the sources will safely yield; and if a severe drought should occur at that time, bringing demands from other cities and towns, as has been the case in past dry periods, a shortage will inevitably occur. If no unusual difficulties are encountered it will take about 6 years to construct the necessary works for diverting water from the Ware River to the Wachusett Reservoir, and from 12 to 15 years after the work is begun to make water from the Swift River available to the Metropolitan Water District.

The plan for securing an additional water supply for the Metropolitan Water District has been so designed that it lends itself in a remarkable degree to gradual development, step by step, and involves no expenditures for temporary or make-shift construction. It thus allows the details of construction to be modified by circumstances and requirements which may appear from time to time.

Beginning with the diversion of the upper portion of the Ware River watershed, the plan provides not only for extension to the Swift River but looks ahead ultimately to a much longer future and a very much larger supply. Water can be diverted into the great reservoir on the Swift River not only from its own watershed and the watersheds of the Ware and Millers rivers as proposed, but also from the Quaboag, the Deerfield and the Westfield rivers, the waters of which will flow by gravity into the great reservoir on the Swift River. The plan proposed will avoid serious injury to water powers on the rivers below by taking only the freshets and the higher flows in excess of about 775 000 gal. per square mile of watershed, per day, which means that water would be diverted in average years only about 43 per cent. of the time; while during 57 per cent. of the time the water would run in all of the rivers, as it does today: that is, from the late spring to early winter there would be no interference with the flow, unless in the case of excessive summer rainfalls when the excess would be stored in the reservoir. In very dry years the period of diversion of water would necessarily be shorter, and little water would be diverted from the rivers during

eight or nine months of the year. The requirements of the district in such periods would be drawn from the great storage in the Swift River Reservoir, which would hold an ample supply for the longest drought for a population very much greater than any which is likely to require a supply from this watershed for many years in the future. Furthermore, when an additional supply again is needed the same policy can be followed of taking freshet flows from the other rivers; and while 200 000 000 gal. per day would be obtained with the development thus far proposed, this quantity can be much more than doubled by similar takings from other available sources.

Incidental to the creation of this additional water supply, the development of water power would be made practicable at several points. At the main dam in the Swift River valley there will be a fall of about 141 ft. in discharging the water, which must be allowed to flow down the stream continuously up to the limit of 1.2 c.f.p.s. per square mile of watershed. At the Wachusett terminal of the tunnel there will be a head of about 125 ft. available for power as soon as the Swift River Reservoir is full; and this head will continue to be available for many years, diminishing in time with the increased draft through the tunnel as the draft approaches its full capacity. It will also be possible by intercepting the Quinepoxet River and thus diverting the water from one of its main tributaries into the tunnel and thence to the Wachusett Reservoir, to utilize the full power of that stream at a very small additional cost, thus restoring the power destroyed when this river was stripped of its power plants in the lower part of its course when the Wachusett Reservoir was built. Additional power will of course be created at the Wachusett dam at Clinton and at the Sudbury dam, while one or two small power developments would be available at other points. The additional power readily obtainable as an incident to the construction of these works would add very materially to the developed water power of the State.

The cost of the entire works when completed is not excessive when compared with the amount of water that will be secured thereby. The greater part of these works will be adequate for a very long period of time in the future and this consideration should be taken into account in the payment of indebtedness created for the construction of the works. The cost of the present Metropolitan water system will in all probability change but little in the next 14 years, though there will probably be a gradual increase in the cost of maintenance, while the total cost per capita will gradually decrease. In the year 1935 nearly one third of the bonds issued for the construction of the present works will become due and the cost per capita charges will then diminish rapidly for the next seven or eight years, when the bulk of the entire indebtedness will be paid. Under these conditions, in financing the proposed new works the construction of which cannot be completed in any case before 1936 even if begun at once, it will be a great advantage if the payments on capital charges are made small in the beginning,

and increased materially when payments on the original net debt begin to reduce rapidly the charge on that account in the year 1936.

The results of a careful study of the financial condition of the district as a whole and its various special divisions, indicates that the income of the district is likely to grow more rapidly than the expense, even including the cost of financing the new system, except possibly in the earlier years before the payment of the existing Metropolitan water debt; and even in that case, by a reasonable arrangement of payments of the new debt, the income of the water works should be sufficient to meet all requirements. Following 1936 the surplus receipts of the water departments will soon greatly exceed the requirements for financing the proposed new works.

In conclusion, it is worth noting that the maintenance cost of water per capita to the municipalities in the Metropolitan district, is generally less, and in most cases much less, than the cost to those municipalities which have remained outside the district and have operated independent works up to the present time. This condition was to have been expected and, even with the financing of the new works added, water will no doubt be cheaper to the inhabitants of the cities and towns of the Metropolitan Water District generally, when a long time in the future is considered, than to those outside.

Discussion.

The President. Gentlemen, this very interesting sketch of a very big piece of work is before you for discussion. I don't know how many of us are able to get an adequate idea so that we can intelligently add much this afternoon, but there are some present who have had to do with this investigation. Dr. Kelley, the Massachusetts Commissioner of Health, is present. Dr. Kelley.

Dr. Eugene R. Kelley. The speaker has mentioned one point that needs emphasis; that is in reference to the first section under the project. The first section, the construction of the tunnel to the Ware River, when built will take care of the immediate water problem for the Metropolitan District and for the city of Worcester. No one can predict exactly how long it will be before the final unit to the Swift River will be required in order to insure ample water supply at all times. We have recommended as our final conclusion, as a Commission, that the first part is imperative and should be done at once, and then we can decide by circumstances which will depend on the growth of population, the increase of consumption per capita and the meterological conditions. Of course it is only safe to assume the output of the absolutely dry years in any water supply prediction. We thought that the decision as to the construction of the final unit could be safely left to the authorities responsible for the construction, completion and putting into effect of the work, simply putting it up to them that the water should be there at the time it was needed.

I don't know as Mr. Goodnough brought out the point that our estimate indicates taking over ten — probably nearly fifteen — years from the time of the beginning of work before the water could be available through our pipes from the Swift River reservoir. Therefore you see it is necessary to allow a considerable time to be devoted to construction work.

THE PRESIDENT. Are there any men here present who are not members of the New England Water Works Association who are our guests to-day and who are interested in this problem?

DR. KELLEY. Mr. President, I would suggest that Mr. J. Waldo Smith, Chief Engineer Board of Water Supply of New York, be invited to speak.

THE PRESIDENT. I have him in mind, Dr. Kelley, as a reserve, but I want to know if there are any men who are interested in this problem, mill owners for instance, some one who may be affected by this proposed development? We would like to hear from any of you gentlemen. Mr. Smith, will you say a few words?

MR. J. WALDO SMITH. Mr. Goodnough has stated the facts so clearly that there is not much more to be said. It seems to me that the problem, reduced to its lowest terms, is: Does the district need more water and from what locality can it be best obtained? The other controlling factors are the size of the population now supplied, the probable rate of growth and the probable rate of per capita consumption. This committee has been working on this problem for two and a half years, and unless one is so imbued with supreme pessimism that he believes this district is not going to grow, or is even going to decrease in population, he must believe it is going to increase, and for this reason must have more water, and must have it in the immediate future. Then comes the question of where such additional supply may be best obtained. Whether it is best to provide a comprehensive plan, looking a long time to the future and which can be developed by successive increments, the first increment amounting to about one sixth of the cost of the entire work; or whether it is best to look only to the immediate future and develop at about the same cost a supply which by no means could ever become part of a large comprehensive plan.

I think this question has been very well answered by eleven out of the twelve members of the committee. They have signed a report recommending a comprehensive plan, and it seems to me that no other plan can receive serious consideration.

The district is very large, and in the past has had a steady growth. I believe it is going to continue to grow in the future, although perhaps at a lower rate than is estimated for many other places. It is true that the water developed at the Wachusett reservoir under the plan of 1895 has lasted longer than was then believed probable, as has been very clearly shown by Mr. Goodnough's diagrams. The rate of increase in the population which was then predicted has not been realized. In view of the experience of these fifteen or twenty years, I think that the estimated in-

creased population as laid down in this report is very conservative. In the district with which I am most familiar, I should certainly have allowed a higher rate. But as finally recommended in this report, my estimate is that the projected increase in consumption will be realized, if not exceeded in the future.

THE PRESIDENT. Prof. Whipple, can you speak on the subject this afternoon?

MR. GEORGE C. WHIPPLE.* Mr. President and Members of the Association: As a member of the joint committee that Mr. Goodnough has referred to, I have taken great pleasure in studying this great problem. No one who has been connected with it can fail to realize its magnitude and no one can fail to realize the excellent work which has been done by Mr. Goodnough and his corps of assistants, which has included a number of the members of this Association, — Mr. Brewer, Mr. Kennison, Mr. Weston, Mr. Hammond, and some others that you probably know. I have been studying this problem along with Mr. Goodnough and Mr. Smith; and being an engineer I have naturally made some estimates of my own in connection with some of these matters, as, for example, the probable future population of the district and the per capita consumption; and I am frank to say that my estimates have not agreed absolutely with those of Mr. Goodnough. No two estimates could be expected to agree exactly. I think that the growth of population will probably be not quite as great as he expects it to be; also that the per capita consumption perhaps will not increase quite as much. And yet I was not able to agree with the twelfth man on our joint board who made the minority report. His estimates of future population and water consumption seem to me to be too low. I think that this district is bound to grow in very much the same way as it has grown in the past, but at a continually lessening rate.

Now there are two or three complicating factors in this water situation which need explanation. If it were a question of the Metropolitan District alone the problem would be a good deal easier to solve than it really is. Mr. Goodnough has already referrred to the city of Worcester and its needs. This city is located near the Wachusett supply of the Metropolitan District, — in fact, its watershed is contiguous to that of the Wachusett area, — and it is very natural that as Worcester is getting short of water she should want some territory for her own supply. It seems to me that it would be most unjust to the Metropolitan District to allow Worcester to take this large fragment of the Wachusett area which she desires. It seems to me that a very much better solution is to provide a supply which can be used jointly by the city of Worcester and the Metropolitan District, and that is the reason why the Joint Board recommended the Ware River as the first extension of the District's water supply. The Ware River will help to take care of the Metropolitan District for a good many years, and it will also provide Worcester with what she needs.

(* Professor of Sanitary Engineering, Harvard University.)

Furthermore, in going west of the divide and taking water from the Connecticut River watershed, it is proposed to take simply the flood flows, not the entire stream flow; and it seems to me that this is the great outstanding feature of Mr. Goodnough's report. While not without precedent even in Massachusetts, the magnitude of this project makes it a notable recommendation. The plan is to take the flood flows only, leaving the summer flows and the low flows of the Ware River just about as they are at present, — I may say almost exactly as they are at present. I think that is a very important matter which deserves careful thought.

Then there is another element in the problem which Mr. Goodnough did not mention, — for lack of time, of course, because he could not speak of all these things in one short paper, — namely, the fact that certain of the present supplies of the District are able to furnish about 25 000 000 or 30 000 000 gal. of water which is not now satisfactory in quality. If I am not mistaken, we may place the present supply of good water in the Metropolitan District at something like 125 000 000 gal. a day. The total supply is more than that, — say 155 000 000 or perhaps 160 000 000 gal. per day, provided that the waters of the South Sudbury and Lake Cochituate are filtered. Now if it were not for the need of Worcester, filtration would perhaps be the logical step to take first, but that would not do Worcester any good. But by building the tunnel to the Ware River we can get just about the same amount of water that could be obtained from the South Sudbury and Cochituate by filtration, we can provide Worcester with what she needs, and can provide a large factor of safety for the Metropolitan District, which I believe is a good thing.

There is another factor which has not been touched upon to-day and was not mentioned, in a conspicuous way, in the report of the Joint Board, and that is the possibility of the development of a large water supply in the valley of the Ipswich River. That project has been proposed a number of times and there is reason to believe that it is a feasible project. The time is coming when the cities in that part of the state, — the Essex County cities — will need to have a great water supply of their own, and if they can make a joint development, if they can create a district in that part of the state and secure a joint supply, it can be made to serve not only as a supply for those cities but as a stand-by supply for the Metropolitan District to tide over a very dry year. You all know that when we say that the supply of the District is 155 000 000 gal. a day, we mean 155 000 000 gal. in a very dry year; that in nineteen out of twenty years we can get more than that, — just how much more depending largely upon the storage provided. If we have at hand a reservoir and a reserve supply which can tide us over this dry period, our present supplies will last just so much longer. And I believe we should study very seriously this Ipswich River problem in connection with the problem of the Metropolitan District. In fact, we have asked the Legislature for an appropriation to enable the State Department of Public Health to make such a study. This study was not made in any

detailed way in connection with the investigation which Mr. Goodnough has been telling us about.

My plan, therefore, based on the report of the Joint Board, would be first to build the Ware River tunnel; and, second, a little later, i.e. when necessary, to filter the South Sudbury and Cochituate supplies; third, to construct the Ipswich River development; and, fourth, at some later date to extend the Ware River tunnel to the Swift River and complete the development which Mr. Goodnough has described. Personally I doubt very much if we shall see that Swift River reservoir in operation within my own lifetime. It may be that it will be necessary, but that will depend upon the growth of the Metropolitan territory and on the feasibility of developing the Ipswich River and other eastern sources. Yet, as an engineering proposition, I believe in the Swift River project. I think it is an excellent one. I think that it will some day be needed and I even go so far as to say that it would be the part of wisdom for the State of Massachusetts to acquire — by right of eminent domain if necessary — the necessary sites for the dams and perhaps to go further than that and obtain by purchase from willing sellers such other land as may be necessary. I believe it would be good business on the part of the State to get some of those pieces of land, even though they may not be necessary to be used perhaps for twenty years or more.

Speaking of the Ipswich River, it may be said that another advantage of a great development there would be to help out the cities of the Merrimack valley. The Ipswich River water is now being taken up or asked for at the hands of the Legislature by various local communities. The Joint Board believes that it would be much better for these cities to pool their issues and develop a supply adequate for all. This Ipswich water would have to be filtered, of course.

Those of you who read the report of the Joint Board, which is now in press, and which will be issued before many weeks will be especially interested, I think, in two or three things which Mr. Goodnough has not mentioned. One of them is the general attitude of the state authorities towards the filtration of the surface water supplies in the state. We have unreservedly approved that policy. We believe that it is only a question of time when practically all of our surface waters will have to be filtered. Personally I believe that the time is not very far distant when the Metropolitan water will be filtered.

You will also be interested in the policy which has been set forth in regard to the use of great ponds. There have been some discussions in this Association, as you know, in regard to boating, fishing, and bathing in reservoirs. A policy has been defined. The Joint Board says, for example, that while from a health standpoint it is quite possible to safeguard the water consumer against infectious disease by filtration and disinfection, every community ought to have the right to say whether it wants to drink water which has been subjected to possible pollution and sub-

sequently purified. In other words, the sentimental objections ought to be considered, as well as the hygienic and economic phases of the problem.

I think you will also be interested in studying very carefully the very important point which Mr. Goodnough has brought up in regard to the use of flood flows. In some respects it is a different method of taking from what has been customary in the past. As you know, the courts in this country do not recognize what is called "compensation in kind." The principle appears to be a good one; it has been adopted already in some places by agreement between the mill owners and the water works authorities. I think that is a matter which this Association ought to discuss very carefully, — perhaps at some subsequent meeting. I mean the general relation between the use of water for power and the use of water for water supply purposes. Let us see if we cannot come to some friendly agreement between the mills who want water for power and the cities who want water for water supply purposes. Both are very desirable things and there ought to be some better way of solving those problems than by going to court every time we have a difference of opinion.

I am sure that you will all be interested in the report when you have an opportunity to read it, and I know that you will all appreciate Mr. Goodnough's paper, just as I have. (Applause.)

ADDITIONAL DISCUSSION OF WATER SUPPLY CONDITIONS AT SALEM, OHIO.

MR. H. F. DUNHAM.* The excellent paper of Mr. Dittoe read at the Bridgeport meeting and the interesting discussion following it brought to the surface two or three inquiries and comments that may be worthy of notice. The work described was carried out in a generation earlier than Mr. Dittoe's and in behalf of fairness and of the Chief Engineer of the Salem Water Company, Mr. E. C. Clarke, the writer begs the favor of a page in your JOURNAL.

The Salem Water Company purchased a small local water plant that obtained its supply from drilled wells almost in the center of the city. With this nucleus a franchise was obtained by Eastern parties who neglected or overlooked sundry facts relating to the difference between glacial drift deposits in Ohio and in New England. Despite protests relating to geology, the insistent demands of the city were finally complied with and a section in the franchise limited the supply to wells and springs. It was necessary to keep up the service from the old wells during the new construction. But at the same time, the weakness and danger in that source were recognized and a favorable area sought outside the city limits for a more abundant supply of softer water, the well water being very hard.

While the location for the new water works pumping station was not all that could be desired, it was fairly satisfactory for the important feature of direct fire protection. With an outside supply to keep the stored water level, at the station, above the surface of the ground as intended, there could be little danger of pollution. It may be noted that under the conditions incident to almost complete and continuous exhaustion of water from reservoirs and wells at that station, pollution was sought scientifically and not detected.

The works were built at the new location and a well drilled to a depth of six or seven hundred feet or down to near the "black shale" which is taken to be everywhere dry. Little water could be obtained. The old wells were connected to the new station by *wrought-iron* instead of cast-iron pipe under the comfortable impression that it would be needed for only a short time and could be more easily removed.

But when it came to an effort to secure a change in the terms of the franchise, complete failure resulted. Then the water company tried to secure a change in the Ohio code that would have removed a very serious handicap and enabled the company to first obtain a better supply and then

* Civil Engineer, New York.

treat with the city for a change in the franchise. At that time no water company in Ohio could exercise the right of eminent domain,— a right that might be about as necessary to a water company as is a charter to a railway company. Only two or three years previous to that time the legislature had passed such an enabling act but in its passage an amendment was introduced making an exception of cities having more than a certain number of inhabitants. This addition to the original bill annulled the whole act by making it "Special Legislation." Apparently it was a simple affair to petition again. One of Ohio's very able attorneys, the late Honorable William A. Lynch,* a leader in the political party then in control of the legislature, prepared and introduced the bill. At the writer's suggestion a clause made it impossible for any water company in that State to ever exercise the right of eminent domain unless all of its purposes and plans had been presented in careful detail to the Ohio State Board of Health and fully approved by that Board.† The Bill was endorsed by the Council of one Ohio city then supplied with water by a private water company. That city, however, was Massillon not Salem. *The Legislature turned down the bill in record time!*

There is an excuse for thus mentioning items from the past for they show the absence of that full coöperation between State and City authorities and private water companies which would have been so helpful in Ohio during that period. Experiences at Newark, Ohio, are readily recalled.

The writer is not familiar with the conditions under which the city of Salem acquired its water works property, but the authorities have been consistent in this, namely, they have continued to secure and accept a very scanty supply of hard water during a period of nearly forty years.

* Mr. Lynch was chairman of the Ohio delegations when Cleveland was nominated for presidency.

† The Bill had the approval and as far as possible the support of the Board. (H. F. D.)

ELECTRIFICATION OF GATE VALVES.

Importance of quick and positive control in preventing property loss by flooding. How the valve operating system works.

BY PAYNE DEAN.*

[*December 14, 1921.*]

Electricity as applied to the operation and the control of large water works gate valves represents an engineering development of relatively recent origin. The remarkable success that has followed the installation of modern electrical equipment in various systems during the past few years has fulty demonstrated the importance of valve control, not only as a labor saving means, but as a safe-guard against the hitherto enormous damage to property due to flooding from broken mains.

Within but a few years the electrical valve control system described herein has almost entirely superseded all other methods of power valve operation, including the hydraulic-cylinder type which had been in use to some extent in the past where conditions were favorable, and where remote control was not essential.

Operating Large Gate Valves.

Large gate valves as a rule do not receive a great deal of attention once they have been installed, but after they have been in service for some years they become exceedingly difficult to operate. It is not unusual for the closing of a large valve to require the combined efforts of six or eight men. In view of the physical effort required it is easily understood why the valve is avoided, and in fact totally neglected in many instances. Under these circumstances, the condition of the valve gradually becomes worse, until when it is suddenly called upon in an emergency it is not fit for operation and hence impossible to close.

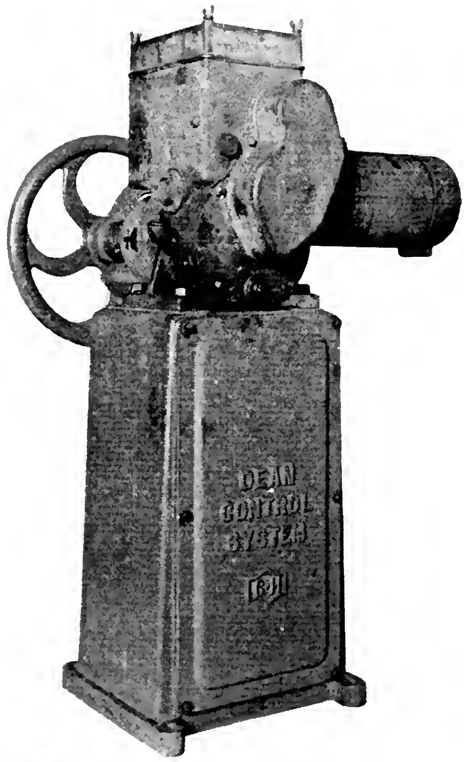
The water works superintendent is obviously aware of the condition of the valves and the more important valves in the system are almost always a source of considerable worry to him. The amount of time and labor required to manually test the valves is so great, however, that in many cases it is a practical impossibility for him to maintain the valves in thorough working condition without neglecting other important work.

Shut-offs take considerable time, and in the event of a break considerable damage may be done by an uninterrupted flow. To be able to close a pair of 36-in. or 48-in. gate valves in from 10 to 12 minutes would at least save a bad washout and considerable property damage. This can

* New York City. Member A.S.M.E. and A.I.E.E.

be accomplished from a convenient point and requires the attention of but one man who has merely to turn a small handwheel.

It is also possible to operate standpipe valves from a remote point. This is important in systems where it is required to pump high pressure directly into the mains. Pump discharge valves are electrically operated in many installations, allowing different pumps to be put into service without loss of time. When an electrically operated pump of the centri-



DEAN CONTROL. FLOOR STAND.

fugal type is shut down, the failure of the check valve to close would probably cause considerable damage. By applying electrical operation to the discharge valve adjacent the check, both the pump and the motor are afforded additional protection as well as greater flexibility of operation and control.

Undoubtedly one of the most important fields for electrical valve operation is in the protection against the serious consequences which might otherwise follow the breaking of large mains. A shut-off may be effectively made where the more important valves are under electrical control, and a portable automotive type of valve closing apparatus is maintained for use

in outlying districts. The portable valve closing apparatus is also useful for operating the numerous small valves of lesser importance and which may be situated at widely separated points.

Valve Control in Congested Districts.

There are certain extremely congested business centers in our large cities that would be subject to enormous loss and serious inconvenience if undermined and flooded. Public buildings, such as art museums and

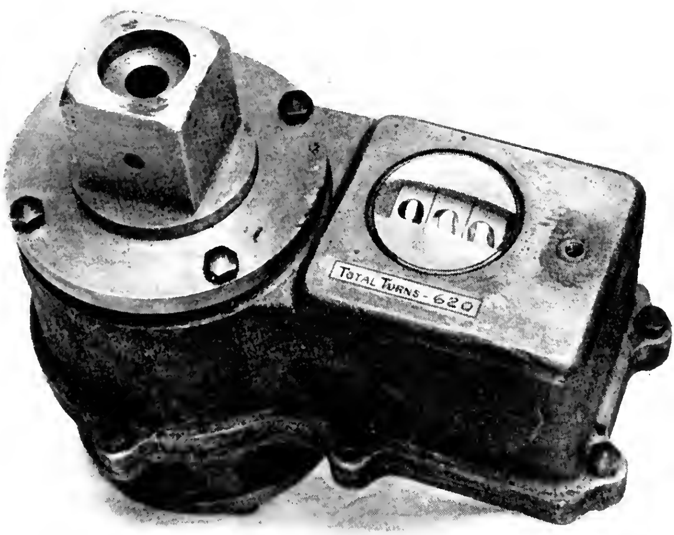
Two 48-in. Electrically Operated Valves in Vault.

libraries housing valuable works of art, would be in serious danger if large volumes of water penetrated through their foundations. Underground railways are especially susceptible to water damage, and while the third rail and other electrical equipment is submerged the system is inoperative.

There are innumerable reasons why consideration should be given to the subject of protection against damage from broken water mains, and it is interesting to know that municipal authorities are beginning to more fully appreciate the savings which may be effected by the installation of suitable valve operating equipment.

Electrical Systems Most Efficient.

Until numerous installations had been made and actually operated over a period of time, there was considerable doubt in the minds of superintendents and others as to the reliability of electrically controlled valves. It is now, however, an established fact that a few well placed electrically operated and controlled valves will afford ample protection for any congested district. Further, it has been shown that electricity affords the only system adopted to meet all of the varying conditions under which valves must operate. Electricity is the most reliable source of power known and is now almost universally available.



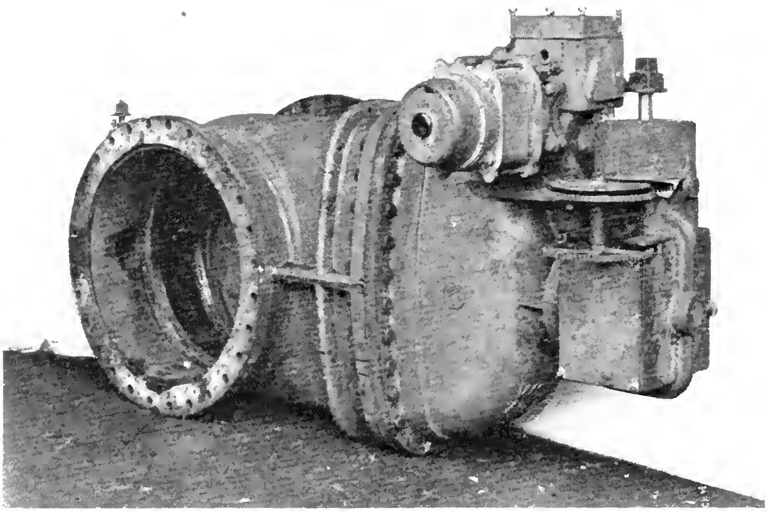
Mechanical Position Indicator.

The design and construction of the electric motor has been carried to a high degree of perfection and dependability. It is available for almost any use and can be made water-tight and able to withstand operation in the open exposed to snow and ice, and even while under water. Obviously the control apparatus can be ruggedly constructed and inclosed in a moisture and fool-proof casing so that a complete system may be built up, all of the operating parts of which are fully protected against outside influences.

By the employment of lead and steel covered cable, the conductors may be laid in an open trench.

Valve Operating Apparatus.

The large valves in street vaults present a number of difficulties for the following reasons. Frequently the valve is very old, corroded and difficult to operate. It is required to be closed against velocity due to break in the line. The control apparatus must be of such a size and nature as to pass through the ordinary man hole. Space is limited in the vault, making it imperative that the installation be made with as little labor as possible. The apparatus must of course be absolutely water and damp



30-in. Inside Screw Valve Fitted with Dean Control.

proof, and should not be affected by water that may collect in the vault. Also standing idle for long periods must not affect the operativeness of the system. The equipment must be self-contained, self-lubricating and unaffected by extremes of temperature. For the protection of the valve the mechanism must be provided with means positively operating to stop the gate at each extreme of its travel.

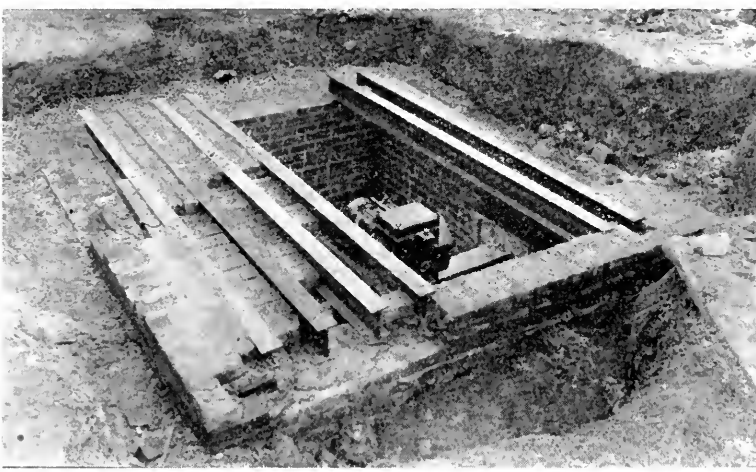
Dean Control System.

This system has been especially developed for the electrical operation of valves and incorporates all of the essentials which long experience has shown to be necessary for these valves. It is the only complete system of valve control that has been devised, and hundreds of installations in various kinds of service are in satisfactory operation throughout the country.

There are five important characteristics of the Dean System —

1 —It is a single standardized unit.
2 —The unit may be attached to existing valves with a minimum of effort and without shutting down the line.
3 —Operation is positive and accurate, and does not depend upon the momentum or drift of the moving parts to seat the valve.
4 — The motor exerts a high initial torque and affords a sufficient reserve of power for operating the valve under various conditions of velocity and pressure.
5 —The complete system is totally inclosed and water-proof.

The Dean Unit embraces the driving motor, reduction gears, and limit trip mechanism all inclosed in a standardized moisture-proof casing. The units are built in a series of types embracing the complete range of valve sizes. Each unit is equipped with feet provided with four bolt holes for attachment to the valve.



Electrically Operated Valve Manhole Cover Construction.

Indicating Devices for Valves.

For showing the position of the valve gate two types of indicators are employed. At the valve a mechanical indicator is installed which shows upon a dial how many turns have been made in opening the valve so that danger of jamming the valve parts is eliminated.

Where it is desired to operate the valve from a distant point an electrical indicating system is employed so that an operator at the remote station can note the position of the gate from a conveniently placed dial. In both of these systems the mechanism is thoroughly protected from moisture and dust by a suitable casing.

Dean Unit.

The motor of the Dean Unit is completely inclosed and water-proof and develops an extremely high torque. The normal speed is 2 400 R.P.M., and through a system of worm and planetary gearing the slow speed shaft which drives the valve stem rotates at approximately 50 R.P.M. The motor and worm shaft are ball bearing and the gearing runs in oil.

The system is furnished for 220 volts, 25, 40 or 60 cycles, single phase A.C., or 110 or 220 volts D.C.

The valves may be controlled from one or more local or remote points, the control stations being provided with red and green indicating lamps showing the position of the valve. The system is applicable to any existing valves whether of the O.S. & Y., or I.S. types without shutting down the line and the valve may be operated manually if the current fails.

Discussion.

Mr. J. E. Garrett.* On the question of a unit which can be operated electrically and also by hand, is it necessary to turn the motor of the electrical control in operating it by hands?

Mr. Dean. There is a clutch that you have to pull out by turning three times around the screw. That declutches it. Ours has a worm drive; and turning the worm, a reversible worm, is quite hard; but even a worm will turn. But, preferably, you have to unclutch to do it. That is the best way.

Mr. Garrett. And when you couple it up again, you automatically put it back?

Mr. Dean. You have to put it back manually. If you do not put it back when you have finished operating by hand, we have indicating lights in the control station and the light shows that it is open. The red light comes up and shows you that there is something wrong in the system.

Mr. Garrett. There is the possibility of getting into trouble if you have hand operated and electrically operated combined?

Mr. Dean. You have to have hand operated and electrically operated combined. The thing to do is to get a safety device to show you that you are not in mesh, as it were, before you start operating by power.

Mr. Garrett. You can't put it back in mesh wrongly, then?

Mr. Dean. No. You only have to turn a handle. But that has been one source of trouble to every operating force in the water works departments, through their overlooking those fine features.

Mr. E. A. Hancock. How accessible is the control for repairs?

* Civil Engineer, Hartford, Conn.

MR. DEAN. It is as accessible as a piece of machinery of that kind can be made. In putting the covers on the vaults, we have them large enought to allow handling the machine. The vault is the worst thing in the world to make repairs in. Of course the atmosphere in a vault is of high humidity and it is difficult to keep it absolutely dry. But we need to go to the extent of keeping all the electrical contacts so that they will operate when we put the juice through them. Our difficulty is principally in constructing a device that is fool-proof, and which can be put into anybody's hands, and I don't know yet whether or not we have succeeded. We are keeping an eye on all we have out.

MR. HANCOCK. Is that furnished for all electrical power?

MR. DEAN. All circuits up to 220 volts. We have stipulated a maximum voltage of 220, because of the inadvisability of putting higher voltage on a small motor. Another thing you want to bear in mind in operating the valve is this: The high strains put on at the time of winding represent the maximum strain that should be put on the windings of the machine, because you do not have any resistance to check the current down.

PRESIDENT SHERMAN. Have you had any trouble with the electric welding of old yokes?

MR. DEAN. We take the yoke out when we can. When the superintendent is not looking we sneak the yoke out. I had a superintendent from Cambridge call me up this morning. My man went away and left some of the yokes off his valves. The man who did it is in Philadelphia. He says he can't operate the valves. We will take the yoke off and weld it and get it back quickly.

PRESIDENT SHERMAN. You find those welds stand up in good shape?

MR. DEAN. Splendidly. They are electrically welded. Sometimes we use thermite, and there is a tremendous strain on that yoke when we test it. There is a strain of some 8 000 foot pounds on the valve stem, and we have found it operates easily enough.

PRESIDENT SHERMAN. Do you have a uniform operating speed throughout?

MR. DEAN. No; the motor is wound and the unit is wound with particular reference to the necessity of shutting the line down, first fast and then slowly. You will notice when a crane pulls out a 10-ton load it goes very, very slowly, of necessity; but when it pulls out a 1-ton load it goes very fast. In shutting down the gate you can go $\frac{5}{6}$ of the way very fast, 12 inches a minute; but when you get to throttling water at high velocity you have to slow down, and the motor slows down until it gets almost to a stop.

PRESIDENT SHERMAN. It slows down sufficiently so that there is no danger of water hammer?

MR. DEAN. I might say that after experimenting and getting the advice of our engineers we have decided on closing mains under all con-

ditions at 3 inches a minute, and no faster. That is what we advise right through. I do not think you will get any water hammer then, at 3 inches a minute. And we gear to suit that. That is what we have been able to find, and that is what the engineers think about right.

MR. GARRETT. What distance from the valve is it economical to operate with a single unit without a relay conduit?

MR. DEAN. About 500 feet. Beyond that distance your copper becomes excessive and you best buy small copper wire and put a relay in.

MR. GARRETT. Beyond 500 feet?

MR. DEAN. Beyond 500 to 700 feet, depending on the size of valve and current required. A large valve takes 120 volts; that is 25 kilowatts.

MR. GARRETT. If at one station the valve is partly opened and left in that position, can the other station close it?

MR. DEAN. Each station has complete control over the valve.

MR. GARRETT. And the indicator in the other station will show what has been done?

MR. DEAN. The lights will show it.

MR. D. L. FURNESS. When you have operated a valve by hand and want to put it back, do you have to put the motor back in the position where you operated it by hand?

MR. DEAN. Oh, no; leave it where it is. In the new units, we are bringing out, the operation will be entirely automatic. That is a matter of evolution in the device we are getting out. I might mention one test that is costing probably $15 000. We have had great difficulty in shutting off high pressure steam in case the line breaks. The ordinary velocity on a steam line going to a turbine has a maximum of 5 000 ft. a minute. If the line breaks that velocity is apt to go up to 50 000 ft. or more. The engineers have put an electrically operated valve in to shut that down. We are having a test where there is 40 000 h.p. of steam available. We are given a 22-in. header and a 10-in. header going to these 40 000 h.p. boilers. There are eight different valves on the header, an English valve, a German valve and several American valves to keep that tight,—that test being carried out under my jurisdiction by the National Electric Light Society, in New York.

SOME OBSERVATIONS ON WATER CONSUMPTION.

BY CHARLES W. SHERMAN.*

[*Presented January 12, 1922.*]

The object of this paper is to bring to your attention some of the things we do not know about water consumption, and especially about what constitutes a reasonable water consumption, rather than to submit any new facts or to draw conclusions from existing data.

Everyone knows that what may be reasonable consumption in one city would represent extreme wastefulness in another, and that local conditions have great effect upon legitimate water consumption. This statement is, however, of little aid in attempting to reach a conclusion as to what is a reasonable consumption for any given case.

It is natural to expect that in the available literature upon water supply, a fair amount of information upon this subject may be had, and that it should be possible with the assistance of various books and publications to obtain sufficient data upon which to base a reasonable conclusion.

To test this assumption let us try the principal sources of such information.

Turning first to the "Water Works Hand Book," compiled by Flinn, Weston and Bogert, 1916, we find (page 545) a chapter entitled "Water Consumption." This chapter begins as follows:

> "*Per Capita Consumption* in U. S. cities and towns ranges approximately from 50 to 400 g.p.d. For communities having service connections wholly or largely metered, it is commonly under 100 g.p.d. and for small cities and towns often much less. For large cities with few meters, but well managed works in good condition, 125 to 150 g.p.d. is a reasonable allowance. Character of industries, climate, and other local conditions have important influences."

The remainder of the chapter is given up to figures upon quantities of water required for irrigation and discharged by lawn sprinklers, and a table upon water consumption in foreign cities. On page 414, however (in a chapter upon distribution systems), we find a table giving the consumption of water for the year 1906 in 19 American cities and towns, which are stated to be well metered. No other significant information upon what constitutes reasonable consumption is to be found in this book.

Referring next to the American Civil Engineers' Hand Book, 4th Edition, 1920, somewhat more and better information may be obtained.

* President New England Water Works Association 1921.

a table giving the consumption in 30 American cities, usually for the year 1917; but there is no information upon which to base a conclusion as to what constitutes reasonable consumption, or upon changes that should be expected with lapse of time.

Failing to find the desired information in recent books, let us try Fanning's "Treatise on Water Supply Engineering," published in 1877. On page 37, Fanning says:

"*Water Supplied to American Cities.* The limited use of water for domestic purposes in many of the European cities during the last half century, led the engineers who constructed the pioneer water works of some of the American States to believe that 30 gallons of water per capita daily, would be an ample allowance here; and in their day there was scarce a precedent to lead them to anticipate the present large consumption of water for lawn and street sprinkling by hand-hose, or for waste to prevent freezing in our Northern cities.

"The following tables will show that this early estimated demand for water has been doubled, trebled and in some instances even quadrupled; and this considerable excess, to which there are few exceptions, has been the cause of much annoyance and anxiety."

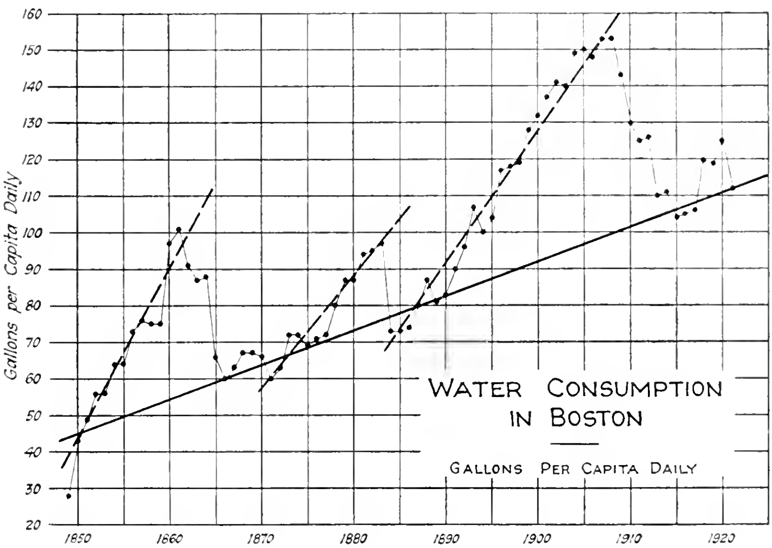
Following this statement is a table of consumption for the year 1870 in 23 American cities, another table showing comparisons between the consumption of 1870 and 1874 in 17 cities, and a third table showing progressive increase in per capita consumption in 13 cities from 1856 to 1874. Fanning states that "the legitimate use of water is steadily increasing," and that owing to the greater variety of purposes for which water is required in larger cities, a greater per capita consumption should be expected in such places.

"In the New England towns and cities, the average daily consumption and waste of water according to population is approximately as follows:

Places of 10 000 population		35–45	gallons per cap.
20 000	,,	40–50	,, ,, ,,
30 000	,,	45–65	,, ,, ,,
50 000	,,	55–75	,, ,, ,,
75 000	,,	and upwards, 60–100	,, ,, ,,

In the files of the JOURNAL OF THE NEW ENGLAND WATER WORKS ASSOCIATION, we find the report of a committee presented March 12, 1931, which contains a vast amount of valuable information, more especially upon the quantities of water required for different classes of service or consumed in various cities at that time, together with some information upon variations in consumption over a limited period of years for a comparatively small number of cities. This information is of much significance, yet very little assistance can be derived from the statistics given in attempting to decide what changes are likely to occur as time goes on.

Turning back to an earlier date, we find a report by Dexter Brackett, on the consumption of water in the Metropolitan Water District in Vol. XVIII for the year 1904. This report, which was drawn upon freely by the committee previously mentioned, contains much of value, but has to do more particularly with the need for metering water in the Metropolitan District as a method of restricting waste. A considerable amount of helpful information may also be found in *Transactions, American Society of Civil Engineers*, Vol. XLVI (1901) p. 407, reporting an informal discussion upon "The Consumption and Waste of Water."



In Appendix II to the report of the Massachusetts State Board of Health upon "A Metropolitan Water Supply," 1895, Mr. Brackett discussed the present and future consumption of water in the Metropolitan District, and this report contains the most complete discussion of changes in consumption as well as reasonable use of any which has come to my attention, not excepting the valuable reports upon the additional water supply of New York. Changes in per capita consumption from 1850 to 1893 are shown for 17 American cities.

Mr. Brackett called attention to the necessity, in estimating consumption for future years, of giving consideration to the great increase in the number of water fixtures and also to the effect of increased pressure in causing greater use and waste of water.

The actual experience of the City of Boston, including the data upon which Mr. Brackett's studies were based, with the figures brought down

to the present time, furnishes a striking illustration of variations in consumption from time to time. The table submitted herewith shows the per capita consumption of Boston from the construction of the Cochituate works in 1849, to 1921. With the exception of the period 1908–1915 inclusive, during which a reduction in consumption was accomplished by the extension of the use of service meters, a general increase is to be noted, excepting only periods when the consumption was limited on account of shortage of the supply, and the period following 1883 when waste was controlled to some extent by the use of the Deacon meters.

It is interesting to note that when a water supply for Boston was first contemplated in 1825, the quantity of water probably required was estimated on the following basis:

"Taking the inhabitants of Boston at 50 000, collected into 8 000 families, and supposing each family to use 60 gallons for washing, and on the same day 40 gallons for all other purposes, we have 100 gallons to each family. As not more than 6 000 families would be likely to wash on the same day, 6 000 families at 100 gallons each and the remaining 2 000 families at 40 gallons each, making 680 000 gallons. Now, if we take the other ordinary demands by the trades and for watering cattle, streets, etc., together with the loss by leaks and waste, at 500 000 gallons more we get 1 180 000 gallons, as the maximum daily consumption, allowing every family to use the water."

This figure is equivalent to 24 gallons per capita daily.

In 1844, when plans for the Cochituate supply were being developed, the commissioners reported that the amount to be supplied should be equivalent to 28½ gallons per capita daily.

As the table shows, the consumption for the first year the works were in operation (1849) was 28 gallons per capita for the entire population. The commissioners probably felt their forecast was justified. This increased very rapidly, however, to 73 gallons per capita in 1856, and 101 gallons in 1861.

WATER CONSUMPTION OF BOSTON, MASS.
In gallons per capita daily.

Year	Consumption.	Remarks.	Year.	Consumption.	Remarks.
1849	28		1890	83	
1850	43		1	90	
1	49		2	96	
2	56		3	107	
3	56		4	100	
4	64		5	104	
5	64		6	117	
6	73		7	118	
7	76		8	119	
8	75		9	128	
9	75		1900	132	
1860	97		1	137	
1	101		2	141	
2	91		3	140	
3	87		4	149	
4	88		5	150	
5	66		6	148	
6	60		7	153	
7	63		8	153	Metering law
8	67	Supply	9	143	
9	67	inadequate	1910	130	
1870	66		1	125	
1	60		2	126	
2	63		3	110	
3	72		4	111	
4	72		5	104	
5	69		6	105	
6	71		7	106	
7	72		8	120	
8	80		9	119	
9	87		1920	125	
1880	87		1921	112	Pitometer surveys
1	94				
2	95				
3	97				
4	73	Deacon			
5	73	meter			
6	74	work			
7	80				
8	87				
9	81				

Note: Records for 1849 to 1893 are for the Cochituate works only; the remainder are for the entire city. The figures for the years 1898 to 1903 have been estimated from those of the Metropolitan District.

Doubtless a portion of the increase was due, as is always the case with a new water system, to the fact that at the beginning a comparatively small portion of the population was actually served, and figures of per capita consumption based upon the total population would accordingly give too low a result. It is undoubtedly the fact, however, that the greater portion of the increase was due to waste and leakage.

It is interesting to note the figures which competent engineers estimated at later dates as representing reasonable and proper consumption for Boston. In 1873, Joseph P. Davis, in reporting upon "An Additional Supply of Water," stated:

"The average daily consumption per inhabitant has varied during the past few years between wide limits, having been ninety to one hundred gallons as a maximum, and somewhat less than sixty as a minimum.

"As the new area to be provided for will undoubtedly contain a less proportion of manufacturing and shipping interests than that now supplied, and as there will probably be means devised at no distant day to check the great waste that has heretofore taken place, an allowance of sixty gallons for each person should, and without much doubt will, be ample."

City Engineer William Jackson in a report upon "The Water Supply of Boston," dated 1886, said:

"*The Proper Allowance per Head of Population.* — As is shown by the opinions of engineers, quoted by Mr. Crafts, the proper allowance per head of population varies largely, and the earlier estimates were much smaller than those of recent years, and also much smaller than the experience of any American cities will at present warrant.

Since the construction of the Cochituate works, in 1848, the facilities for the use of water as well as the uses to which it has been put have been constantly increasing not only here but throughout the world.

In 1857 there were 48 000 house water fixtures connected with 20 000 services in the city of Boston; in 1885 there were 188 000 fixtures supplied from 52 000 services. In other words, the number of fixtures per service had increased in twenty-eight years from $2\frac{1}{2}$ to $5\frac{1}{2}$.

* * *

"That a certain portion of the water supplied in Boston is wasted, and that the present consumption per capita can be reduced to some extent, is not disputed; but in view of the previously stated fact that the efforts of the past three or four years have not reduced the consumption below 70 gallons per head, it is not deemed safe or advisable to use a less amount in considering the future requirements of the city."

In his 1895 report cited above, Mr. Brackett does not give an estimate of the reasonable consumption of Boston, but states that in estimating the requirements of the entire Metropolitan District for the succeeding 30 years, a consumption of 100 gallons per capita daily should be assumed. This may probably be assumed as equivalent to about 120 gal. per day for Boston.

In the report of 1903, his estimate was that *if waste were not prevented,* the per capita consumption of the District should be expected to increase from 134 gal. per day in 1910 to 174 gal. in 1930, (corresponding roughly to 160 and 205 gal. per day for Boston); and that if waste were prevented, the corresponding figures would be 80 and 100 gal. per day for the District (95 and 120 gal. for Boston). For 1920, his figure would have been 154 gal. per day for the District if waste were not checked, and 90 gal. if waste were prevented (180 and 105 gal. for Boston).

The experience of Boston has been cited as more or less typical of that in the larger American cities, and indicates how difficult it is to draw a fair conclusion upon reasonable consumption at the present time, much more so for a future period. In view of the present conditions in Massachusetts with the probable need for an early extension of the water supplies of some of our important cities, it is a subject to which serious consideration must be given and upon which it is most important that sound conclusions be reached if proper provision for the future is to be made.

TOPICAL DISCUSSION: CAN HIGH-VALUE WATERSHED LANDS BE PUT TO PROFITABLE USE?

[*September 15, 1921.*]

Mr. Samuel P. Senior.* Mr. President and Gentlemen: Some time ago Mr. Sherman came to Bridgeport and asked me to write a paper about Bridgeport's water supply. I told him I would do it. And I also told him that I would like to ask a question about watershed lands.

The problem I want to ask about is this — by the way, I have never heard it discussed or seen a reference to it in any of the publications of the various engineering societies. In the case of rough and rather cheap lands it is customary, I believe, for water companies to plant conifers, such as white pine, red pine, and so forth, and get some return in that way. But the thing I want to know about is regarding land of better character and higher value. For instance, we have perhaps 1 000 or 1 500 acres of land that is valued at $200 or $250 an acre. Manifestly you could not expect to get a return from land of that value by planting pines or other conifers.

The question is, What are you going to do with that land? If you allow it to take care of itself in a few years it will grow up to white birches, briers, and so forth, and your land which cost $200 an acre will be worth, perhaps, $25 or $30. So that the problem is to keep that land up to its initial value.

I would like to know what the various members do with land of that kind. We have an agricultural account which, I think, runs up to about $90 000 a year for work of this kind. We have tried potatoes and corn, and other forms of crops, but the difficulty is right here, in my opinion: a farmer can live and make a living from such land in this locality where he keeps cows in connection with the farm work. He can with the same amount of labor keep 12 to 15 cows, and from them get a daily income, and in addition to that get fertilizer that he uses to take care of his crops. We failed to show a profit on potatoes, corn, and similar crops. In fact, found that we worked at a loss, and for that reason.

At the present time most of our land we are getting into grass and sell a great deal of standing hay. We also cut a lot of it, bale it and sell it at the best price we can get. The idea of getting it into grass is that less labor is required on land so planted than anything we know about.

We also are experimenting with orchards. There are about 100 acres now planted to standard apples, and in many cases peaches are grown in between the apples and we have marketed some peaches. We have some

* President Bridgeport Hydraulic Company

apple trees that are nearly old enough to bear. As you know it takes about eight years to get a crop of apples.

Mr. J. W. Diven.* The main, if not the sole object and reason for purchasing watershed lands, is to protect and improve it as gathering ground for the water supply, not to make profit. If the land is to be used or leased for ordinary farming purposes then why buy it? Unquestionably forestation is the best way to use such lands, the way that will most improve them as gathering grounds and that will most improve the water supply from them. Cropping them, using them as pasture lands, cultivating them will not improve the quality of the water gathered on them, in fact will leave them about as they were under individual ownership.

But if not satisfied with the slow asset of timber raising, or if the land is not suitable for that purpose or is considered too valuable, then the consideration becomes what can be raised on it that will have the least injurious effect on the water supply. This will depend largely on the character of the soil. But it should be always borne in mind that the least the land is " worked " — plowed, cultivated or in any way broken up — the better. Plowed land will, with heavy rains, wash into the streams, reservoirs, etc., making the water turbid, as well as carrying with it many impurities and injurious substances. If the land is suitable for hay,—and most of our northern hill lands are — that will be among the most suitable crops for watershed lands. On the ordinary hill soils hay crops will run from four to six years without reseeding, possibly with proper care, late fall and early spring seeding on the sod, it will run much longer. Alfalfa, if the soil is suitable, would be a better crop, as it stands longer, and its tough and deep roots would best prevent gullying and washing of the land. Either are profitable crops and require little working. With the modern farming machinery, tractor propelled, it would not even be necessary to go on the land with horses, thereby eliminating one possible source of contamination of the supply.

Fruit orchards or nut groves would entice the small boy to trespass, and surely the fewer people permitted on the watershed the better, for any one might be a typhoid carrier and cause serious contamination, resulting possibly in an epidemic. Fruit orchards to be properly cared for and protected would mean the dwelling on the land of many people, always a source of danger. Orchards require considerable care, the using of chemicals that would not be considered pleasant in drinking water, among other things, and they surely require close watching if the owners are to reap any benefit or profit from them. Nut trees require little care, but do need guarding, and in places remote from residences are considered by the small boy as common property.

It may be argued that leased lands can be better controlled than privately owned, that proper restrictions and regulations can be made. The speaker's experience is that the restrictions are hard and costly to

* Secretary American Water Works Association.

enforce, the lessee naturally wants to get all he can from the land, and, unless his lease is to be a long one, apt to get from the land all he can, putting as little as possible into it, so that the land would soon be exhausted, worked out and unfit for farm land. Perhaps this would be a good, as well as a logical, solution of the problem, as there would be no high value land to be considered and forestation would be the final outcome, and the best watershed protection be accomplished.

MR. ALLEN HAZEN.* But little of the land acquired for water works purposes in New England and the adjoining states has been sufficiently valuable to make this question important. Ordinarily devoting the land to forestry seems to be the best solution. There are, however, places where much more valuable agricultural land has been taken for water supply purposes. In California some very valuable land has been so taken.

The Spring Valley Water Company, supplying San Francisco, has perhaps the largest holdings. It owns about 100 000 acres of land. This includes several million dollars worth of very productive land. The company is not able to operate that land directly at a profit, but what it has done has been to organize an agricultural department with a very competent superintendent who finds out what each parcel of land is fitted for, and can be used for without injury to the water supply and then leases that parcel, restricting its uses to these purposes that he has decided upon. The leases provide strictly what tenants can and cannot do, and they contain all the provisions which are thought to be necessary to protect the water from pollution. These conditions vary according to how the land is located. Some of it where the conditions make it suitable, is used for general agricultural purposes and is cultivated and cattle kept upon it. In other locations closer lines are drawn. Areas about reservoirs may not be ploughed and cultivated, but they have been leased for grazing purposes. Sheep are found to be cleaner than cattle, and sheep have been permitted in certain places where cattle would have been regarded as objectionable.

The agricultural operations of the company have resulted in substantial net profits, running up to something approximating $200 000 per annum and this is quite an important aid to the company in carrying these valuable lands that are necessary for protecting the quality of the water supply. From an accounting standpoint there are some practical difficulties. As you know the state supervision of public utilities of California is very close and the state officers find it difficult to satisfactorily audit these agricultural accounts. One way out of the difficulty that has been talked of but not yet adopted, would be to form a subsidiary land company making a contract with the water company for the management of lands and completely separating the accounts from those of the water company.

---

* Consulting Engineer, New York.

Mr. William A. Mackenzie.* I have not had personal experience along the line of utilizing the higher priced land in the watersheds of public water supplies. Wallingford has had success planting Norway and Scotch pines, but I can not predict how it will turn out from a financial standpoint.

However in my section there are a large number of apple and peach orchards. These lands on the rolling hills have been bought for a nominal price and then by planting apple and peach trees in alternate rows they have yielded a good profit within a few years.

I have in mind one farm in particular where I do not think the present owner paid over $5 000 for an 80 acre-farm. The apple trees have been bearing about four years and this year his entire crop of peaches and apples was worth about $45 000, and he was offered $100 000 for the property with this year's crop. But the owner stated that his lowest price was $125 000. The owner is not a farmer and does not live at the farm or keep any stock on the premises.

I believe high-priced sections of watershed lands can be set out to apple trees and with expert care show a profit within a reasonable length of time.

Mr. J. E. Garratt.† The experiences that we have had at Hartford may be of some interest. The lands that Hartford bought for its new water supply were of many kinds, of course, and amongst those lands were orchards that perhaps would not run as the best quality, but they were orchards that bore fruit. Our experience has been that the best proposition is to cut those orchards down and get rid of them because of the fact that to care for the fruit and to get it for our own use would require such a guard that it would hardly pay to save that fruit. I wonder if you did go into the fruit business whether you would be able to save it for yourself, or whether, as water-works lands are located, being separated from the populated districts, the fruit would be taken care of by others.

Mr. Theodore L. Bristol.‡ Our problem is considerably, I think, like Mr. Senior's. We tried everything to get some revenue from our lands. We first started in setting out some pasture land to chestnut, planting the nuts themselves, and then installed a nursery and planted seedling chestnuts from the nursery. Of course, most of those are gone. Then we tried white pine, and some of the stock came from Germany and was infected, and a good deal of that has gone. Now we are planting red pine.

Then we tried chemical fertilizing and green manuring. No stock was kept on this property, so tried green manuring by ploughing under rye. That was a failure, — I think perhaps because we did not understand how, although we had a farmer in charge.

Then we tried sheep and started in with a man who knew his business. The highest number of sheep was 400 and when we got through

* City Engineer and Superintendent Water Works, Wallingford, Conn.
† Civil Engineer, Hartford, Conn.
‡ President Ansonia, Conn., Water Company.

we were $3,500 out of pocket, and hadn't any sheep. At the present time we are trying to keep the land that is not too poor in grass, but hardly get our money back for taking care of it and keeping it up, re-seeding, and trying to make grass land out of it. We have tried alfalfa, that was not a success.

MR. DIVEN. You did not try it right; you forgot the lime.

MR. BRISTOL. No; we bought carloads of lime, — a great many carloads of lime — and have used fertilizer. You have to treat the soil with bacteria. I do not think there is a speck of that alfalfa left. We had a fair stand to start with, but the second year there was none left, having been winter-killed.

Now I think our principal revenue is from cider apples. The only way I can see that we can make any money on cider apples is to sell somebody the output of the orchard and let them watch it, because we could never keep any apples on the orchard ourselves. I think if we told somebody that they could have those apples at a certain price, they would watch the orchard to see that nobody got them.

MR. HUGH MCLEAN.* It is a question in my mind whether or not we are putting our efforts to any good purpose when we are trying to do something with our farm lands. We have got about 3,500 acres. We have gradually been accumulating farm after farm. But it does seem that there should be some power somewhere that would compel the water commissioners to put that land to some use. We have taken it away from productive possibilities. We buy a 200-acre farm, which was formerly capable of taking care of 35 or 40 head of cattle and raising crops, and it is abandoned. The buildings are taken down and everything goes to seed. Whether it is in the form of reforestation, or whether it is in the form of fruit trees, or grass and hay in some form, it seems to me that there should be something worked out through our agricultural colleges, which we maintain by taxation so that we will have some service rendered and advice given us as to what it is best to do.

Two years ago, having that in mind, we set out about 500,000 pine trees on our watershed. Now, is it going to be profitable? Some people say that we can sell them for a million dollars in thirty years; and if in thirty years time they are worth a million dollars, we have done the public a good service.

Is there any other tree that might be set out? For instance, the black walnut? I understand that the black walnut of the country is about gone. It might be possible to set out forests of black walnut if the lands are adapted to them. We ought to clean up the forests, and set out something that will pay.

We have had quite a good many fruit trees on our land, but they have grown old and are not profitable, so we decided to cut them down and

* Water Commissioner, Holyoke, Mass.

set out something that would be profitable. I think the pine trees will preserve the purity of the watershed, and will bring us a harvest in time unless a fire gets into them. I think we ought to be compelled to do something by the state.

MR. M. N. BAKER.* As a general proposition I should suppose that there would be no question but that forestry work, even for relatively high-priced lands, might in the long run be the best thing. It has been common in Europe, as many of you know, for generations, and in some cases for centuries past, for cities to maintain municipal forests. If this matter were taken up in a broad-minded and scientific way with proper coöperation, it seems to me that forestry, in the long run, would be found to pay. We certainly have got to do something in this country to provide for the future timber supply. I know by my own experience that so far as any immediate returns are concerned, it is entirely out of the question for a private individual to replenish denuded lands by planting forest trees. I planted some 50 000 trees (cuttings and transplants) on an Adirondack farm that I sold recently. I did it for amusement and for the pleasure of seeing them grow, and I feel I got my money back from that viewpoint, but of course only my children would have reaped any direct profit from these plantations, had I retained the land, unless I should have been so fortunate as to live and retain my faculties to a ripe old age. Doubtless, I sold the farm to better advantage because a considerable part of it had been reforested.

I believe the Massachusetts forestry tables are the ones generally cited in this country as to the possibility of revenue. They show a slight return from white pine, after only some twenty-five years. The white pine experience has been somewhat disastrous on account of the blight, and attention now is being given to planting other species of pine. I found in my own experience that for immediate results the Scotch pine was very much better than the white pine in the Adirondacks. (I never had any trouble with blister or any other disease.) The Scotch pine takes hold much more quickly and makes much more rapid growth than the white pine. When it becomes marketable it will not be worth as much as the white pine, however, and that has to be taken into consideration.

Reforestation must be regarded as a long range proposition, and it should be taken up in a very broad way. In a number of states there is no difficulty whatever for a city or private water company to get all the coöperation that they may reasonably desire from the state in which they are located. In New York and in Pennsylvania, — and I dare say the same is true in other states, but it is conspicuously notable in those two states — an immense number of young trees have been set out on water works drainage areas.

* Associate Editor, *Engineering News Record*, New York.

Mr. X. H. Goodnough.* I believe the planting of forest trees on watersheds is becoming quite common in Massachusetts from what I have learned from the State Forester and elsewhere. Many of the cities have purchased forest trees and are beginning forestry on their water supply watersheds.

As to profit from forestry, I think that the Forestry Department published some years ago a statement in which they said that after 25 years a little income might be obtained but that in 30 or 35 years the income would be a better one and eventually, on the basis of the recent price of pine, they believe that an income of $7 an acre can be obtained from the pine lands. That would be all profit, as I understand it.

The planting of forests is about the best method of utilizing the watersheds of public water supplies, as I see them in Massachusetts. Most of these watersheds are rough lands not adapted to general farming and forestry is handled very well on some of those watersheds.

The Agricultural Department appears to think that such lands can be used for grazing. The land varies greatly of course as to the number of animals it will support. Some pasture land will support quite a number of sheep per acre — something like 5 to 7 — but it appears that such a number of sheep would require better than the average pasture land so that it is safer to estimate on 5 or 7 sheep on 2 acres of the kind of pasture land that is ordinarily met with in the various watersheds.

Orcharding could not be handled as a rule by municipal authorities, and in order to handle it properly of course it has to be dealt with by long leases. I do not know of any place in Massachusetts where orcharding has been tried, but I think the general feeling is now that the pine crop is something that is worth trying, and has so far been pretty successful. There has been no very great loss as yet from fires. There was one large fire in New Bedford several years ago, but other than that I have not heard of any large losses from fires in pine lands within water supply watersheds.

Mr. Rudolph Hering.† It seems to me when we are making such improvements in the purification of water that it may not be very far distant when we shall purify all surface water and give up the possession of watershed lands from which we expect to get fairly pure water. Therefore, I am somewhat in doubt about how to answer Mr. Senior's question. It depends a good deal on how much we can absolutely guarantee in the way of purifying water from small, as we do now from large, streams, where the cities do not own any territory at all but rely entirely upon the purification of the water. Now, if we can filter and purify the water satisfactorily from the smaller areas, in time we shall not be required to possess large areas of watershed land where the difficulties that have just been mentioned by the speakers will arise.

* Chief Engineer, Mass. State Dept. of Public Health.
† Consulting Engineer New York.

Mr. Bristol. I would like to ask if anybody has leased the berry privilege on their lands. We have a lot of berry pickers that get a lot of revenue from our land.

Mr. Diven. Keep the berry pickers off.

Mr. Bristol. It is some job.

Mr. William J. Willson.* I would like to ask Mr. Senior regarding the care of these trees,—whether the underbrush is cut down and some expense incurred in caring for the trees, or are they allowed to grow without care?

Mr. Senior. We usually clear the land the year before we plant it, and then I think you would have to clear the brush overhead about twice before the trees got big enough to take care of themselves. Clear the land where the trees are planted and then in a few years you will find that they are being over-topped because they have not sufficient start to get ahead of the underbrush; and a few years later it is quite likely you would have to cut it out again. We have been having trouble with just that thing this summer, and it is a question whether it pays in some cases. The underbrush gets a start, and it costs a lot of money to cut it out. In some cases we have actually left it and let it drive the pines out, because the cost was prohibitive. To raise the conifers to commercial size is a difficult thing, and it is a question in my mind whether it ever pays, even in rough lands, because of some of those practical costs.

Another thing is fire. You lose a lot of them through fire. Those of you who have had to clean up brush land for your reservoirs know that the cost is a very real item. If the brush gets in there it will crush your pines down when you go to cut them. And it costs too much to handle the wood and carry it out, so that you can't get anything for it. There are quite a few practical difficulties.

A lot of you have said that raising orchards would not pay because your fruit would be stolen. I do not think there is anything to that at all, because there are commercial orchards all over the country that have very little trouble. If you have trees enough in one locality — and you must have, to make it worth while — you can protect them without any trouble. In fact, you have to have a man on duty there while the apples are ripening, and perhaps have a couple of dogs there, or something like that.

There is a man here named Jackson who has made a very great success of his orchards. Last year he sold a thousand barrels of the Mackintosh apple, worth $10 000, off land that he planted a few years ago, which only cost him $10 or $15 an acre — cut over land. I do not see why, if he can do that, we cannot do it. And we are trying it on a comparatively small scale.

What I wanted to bring out to-day is, what are you gentlemen doing? not what is your theory about it, so much as what are you doing now? It is a condition, not a theory. I am telling you what we do, and I would like to know what some of you are doing to-day. It is a big problem.

---

*Superintendent Water Works, Greenwich, Conn.

You have thousands of acres of land, good, fertile land — and what are you doing with it? Are you allowing it to grow up to briers and go back to cheap land, or are you planting it, or what are you doing with it? That is what I want to know.

Mr. Garratt. In Hartford most of our land is rough land. The amount of fertile land, meadow land, was relatively small and was near the reservoirs. On rough land we have a definite forestation plan, whereby each season we plant about 30 000 pines, red, Scotch and white. The brush on those plantations is kept cut for the first few years. It is an expensive proposition to grow them now, but what they will return in the future we are not in a position to say.

The open land, the good land near the reservoirs, we are planting to grass. It is plowed and fertilized with commercial fertilizer, treated with lime and sowed down.

The land that is already forested is trimmed out as our force allows and made into lumber, cord wood, ties and telegraph poles.

Mr. McLean. I think it has been established that it is possible to take care of the land if it is nothing but a forest. We have men who haven't much to do in the winter time, and instead of letting them be idle it is best to send them into the woods to chop down the wood and sell it; otherwise I think we will be compelled to give up the land to the people who own it and who do something with the soil, and filter our water. If the boys steal the fruit off the trees, that can be easily stopped.

Mr. Baker. I hope the idea won't get abroad that everywhere there is such a serious struggle between the forest weeds, as they are called, and the pine that are planted, as seems to be the experience in some places. I do not question that it may be true here in Bridgeport, but probably several if not many of those present know of good pine plantations in this country and elsewhere where there has been absolutely no trouble, or only very insignificant troubles with other growth. If the trees are properly spaced, in a very few years pine will completely cover the ground. One area in particular which I planted about ten years ago has grown up so that it is next to impossible for anyone to walk through it, the ground is so completely covered, the branches from one row of trees interlocking already with the branches from another. And that is my general observation wherever I have seen forestry work being carried on. There may be places, of course, where some of the softer woods do get in and grow so rapidly that they choke out the pines, but I think experience will show that after fifteen or twenty years the pine will be in the ascendency. The pine is a rapid grower and I think will destroy everything else.

Mr. Senior. The difficulty we have is in cut-over land. You would not experience that on pasture land.

Mr. Diven. I think in the long end of the struggle you will find that the pine will win.

THE DESIGN AND CONSTRUCTION OF THE GLOVERSVILLE STANDPIPE.

BY FRANK A. MARSTON.*

[*January 12, 1922.*]

The City of Gloversville, well known because of its extensive leather and glove industries, is located in the easterly portion of New York State about forty miles northwest of Albany. Its population in 1920 was 22 026.

The main water supply is derived from a number of creeks located at a distance of from three to ten miles from the city and at sufficient elevation above it to enable the supply to be distributed by gravity.

The water consumption of Gloversville varies widely, depending upon the activity of the tanning industry. In the period from November, 1919, to March, 1920, within which the tanneries were very active, the average water consumption was 2.8 million gallons per day, with a maximum rate of from 4.5 to 5 million gal. per day, and the average per capita consumption amounted to 127 gal. per day. By contrast, during July, 1920, when the tanneries were shut down, the average water consumption was 1.75 million gal. per day, with a maximum rate of from 3.0 to 3.5 million gal. per day, and the average per capita consumption amounted to but 80 gal. per day. The services are nearly all (99.2%) metered.

With the tanneries in full operation the maximum demand for water, from these industries, during the daytime, has been sufficient in the past to reduce the normal water pressure in the center of the city, from about 90 to about 65 lbs. per square inch.

According to the standard regulations adopted in 1916 by the National Board of Fire Underwriters, the maximum rate of demand for water at fires is approximately 4 760 gal. per minute, or a rate of 6.85 million gal. per day, computed by the formula, —

$$\text{Gallons per minute} = 1020\sqrt{P}\,(1-.01\sqrt{P})$$

Where P = population in thousands = 24 (estimated) 1935 population.

This maximum rate is to be taken in addition to the ordinary maximum water consumption demand based upon: "The maximum consumption for 24 hours in the past three years . . . unless conditions have so changed that this maximum will not occur again."

It is further required that for cities of 2 500 population or over, "ten hours' fire flow could be obtained."

The fire demand rate of 6.85 million gal. per day for a period of ten hours requires a total amount of 2.86 million gal. To provide water storage to meet these conditions would require the construction of a reservoir,

* Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.

preferably of at least 5 million gal. capacity. Such a reservoir has been proposed as a part of the future construction program of the Water Works Department; but in view of the financial situation of the Department and the need of reinforcing the distribution pipe system, the local authorities felt that the cost involved by the construction of a reservoir of 5 million gal. at the present time was not warranted and that the expedient of building a standpipe with a capacity of about one million gallons would tide over the situation until some future time when a larger appropriation could be made.

From the point of view of fire protection the standpipe, by reason of its small capacity, would have but little effect. During the first hour or two of the fire, to be sure, unless the number of fire streams used was large, the pressure would be somewhat increased by the standpipe storage; but in a prolonged fire requiring upwards of a million gallons of water, the influence of the standpipe would be nearly negligible.

The standpipe will, however, have the effect of maintaining higher water pressure in the center of the city during the hours of the day when the demand from the tanneries is such as to reduce the available pressure to below desirable limits. In designing the standpipe it was assumed that its effect would be to limit the minimum pressure to 72 lb., more or less, (with the tanneries active) whereas in the past during the daylight hours (from 8 A.M. to 3 or 4 P.M.) the pressure has sometimes fallen to nine pounds, more or less, below this limit, as actually recorded by the gage in the Water Department's office.

During periods of depression in the tanning industry the maximum demand for water will be less and it is expected that the pressure will be maintained at somewhat higher figures.

Design of Standpipe.

After studying several methods of improving the pressure in the distribution system, and taking into account the various conditions involved it was decided to construct a steel standpipe, 60 ft. in diameter and 55 ft. in height, on high land near South Eagle Street in the southern part of the city. Drawings and specifications were prepared by Metcalf & Eddy, Consulting Engineers, Boston, Mass.

The standpipe rests upon a reinforced concrete foundation, and has been so located that the top of the tank is 5 ft. below the overflow level of the spillway of Rice Creek inlet, — the nearest of the several reservoirs supplying the city. Near the base of the standpipe, a 12-in. Ross pressure regulating valve has been installed, to prevent water from overflowing the top of the standpipe at times of unusually low consumption. Under the usual operating conditions, even with the minimum weekday demand, overflow is not expected to occur, due to the friction loss in the distribution system. As a protection in the event of accidental overflow, however, provision against serious damage has been made in the grading of the stand-

pipe lot and by the construction of a concrete walk around the structure at its base.

By thus locating the standpipe and providing against overflow a saving of 5 ft. in the height of the structure was realized, and its capacity made more available than would have been the case with a standpipe of equal capacity but with the top carried to the same elevation as the spillway of the reservoir.

As the cost of housing a standpipe is substantially equal to that of the standpipe itself, one of the first questions to be decided was whether or not it would be necessary to roof, or to completely house, a standpipe such as this in an exposed location.

The temperature of the water in Gloversville, during the winter, is but slightly above the freezing point. Observations made by Mr. Alexander Orr, Superintendent of the Water Department, indicated temperatures of from 36 to 38 degrees Fahrenheit between February 10 and February 14, 1920. It is to be expected that a temperature of the air of from 10 to 20 degrees below zero will be reached on several successive days, with the maximum temperature at such times but little if any above the freezing point. In order to be thoroughly informed as to what experience has shown regarding standpipes of different kinds and dimensions, a questionnaire was prepared and sent to about 300 water works located in the northern part of the United States and in Canada. The results of this inquiry were reported in a paper entitled " Experiences with Ice in Standpipes ", presented by Mr. Leonard Metcalf and published in the JOURNAL OF THE AMERICAN WATER WORKS ASSOCIATION, Volume VII, No. 4, July, 1920, pages 578 to 588.

The records fully established the fact that an open standpipe could be used safely in Gloversville, despite the cold winter climate. Furthermore, the comparatively large diameter of the standpipe (60 ft.) decreased the likelihood of trouble from floating ice or from ice forming against the cylindrical sides to an objectionable thickness.

No overflow pipe was provided, since it was believed that if constructed on the inside of the standpipe it might be torn out by ice action, and if on the outside it would soon become frozen, in case of overflow, and thus rendered useless.

SPECIFICATIONS.

In writing the specifications it was the intention to state the requirements in such a way that the bidders might be able to make use, as far as possible, of their own standard forms of joint, methods of construction, economical width of plate, and certain other features which would not affect the strength or durability of the standpipe, but would result in a material saving in cost.

Only certain portions of the specifications, of especial interest, will be mentioned.

Stresses.

The specifications required that all parts of the structure should be proportioned so that the sum of the dead and live loads would not cause the stresses to exceed those given in the following table:

Tension in plates forming sides or bottom of standpipe..........	12 000 lb. per sq. in. of net area
Shear on rivets	9 000 lb. per sq. in.
Shear in plates....................	10 000 lb. per sq. in.
Bearing pressure on rivets..........	18 000 lb. per sq. in.

The above allowable stresses are somewhat lower than those frequently employed for standpipes and other steel structures. The additional cost involved by the thicker plates required, appeared to be justified in view of the conditions of extreme cold and exposed location, to which the standpipe is subjected.

Plates and Structural Shapes.

"The bottom of the standpipe shall be made of steel plates $\frac{3}{8}$ in. in thickness, with single riveted lap joints."

"The sides of the standpipe shall be made with courses of steel plates varying in thickness from $\frac{5}{16}$ in. to 1 in. The stresses determining the thickness of any circumferential course of plates and the design of the vertical joints shall be the stresses computed at the line midway between the double row of circumferential riveting at the bottom of the course."

While it would have been possible with high efficiency joints to use a somewhat thinner plate for the lowest course of side plates than that specified (1 in.), it was deemed prudent, in view of all the conditions, to provide the thicker plate. One consideration which led to the adoption of this thicker plate was the fact that the results of examinations of old standpipes indicated far more serious pitting of the plates in the lowest course than in any of the other courses.

It will be noted from the above that no limitations were placed on the width of plates to be used, making it possible for the manufacturer to adopt such widths as might prove most advantageous from his point of view.

"The plates forming the sides of the standpipe shall be of such diameters that the courses shall be cylindrical and shall overlap each other inside and outside alternately.

"The circumferential joints shall be *double-riveted lap* joints. The vertical joints shall be *butt* joints with *inside* and *outside* straps."

"Rivets shall be spaced so as to make the most economical and watertight seam. The butt joints shall be so designed as to develop an efficiency of at least 70 per cent.

"The lowest course of the side plates shall be connected to the bottom plates by means of a 6-in. by 4-in. by $\frac{1}{2}$-in. steel angle placed on the inside, with the 6-in. leg double-riveted to the side plates.

"The top of the tank shall be stiffened with a 3-in. by $2\frac{11}{16}$-in. by $\frac{3}{8}$-in. Z bar placed on the outside."

Quality of Steel.

It was required that all of the steel should be made by the open hearth process conforming to the requirements of the standard specifications of the American Society for Testing Materials.

For the plates "flange steel" was specified, having a tensile strength of 55 000 to 65 000 lb. per sq. in.

Planing and Drilling Plates.

"All caulking edges of plates and of the butt straps shall be bevelled slightly by planing.

"In plates $\frac{3}{8}$ of an inch or less in thickness the rivet holes except for butt joints may be punched full size from the faying surface of the plate.

"In plates more than $\frac{3}{8}$ inch and less than $\frac{7}{8}$ inch in thickness and for butt joints in thinner plates, the rivet holes may be either drilled full size, or punched at least $\frac{3}{16}$ inch less in diameter than the finished diameter, and drilled or reamed to the finished diameter.

"Rivet holes in plates $\frac{7}{8}$ inch in thickness or greater shall be drilled.

"The finished diameter of all rivet holes shall not exceed the diameter of the rivet to be used by more than $\frac{1}{16}$ inch."

Proposals for Construction.

Bids for the construction of the standpipe were opened April 5, 1921. Seven bids were received, as shown in Table 1, the lowest being that of the Pittsburgh-Des Moines Steel Company. The estimated weights shown were computed by Metcalf & Eddy. It will be noted that the estimated price per pound varies from 7.5 cents to 11.4 cents per lb. for the steel standpipe erected, including sand blasting and painting, but exclusive of the reinforced concrete foundation, which was constructed under another contract.

It is of special interest to compare the proposed thicknesses of plates and widths of plates as submitted by the several bidders, inasmuch as the bidders were only limited in regard to the minimum and maximum thickness of plates. The accompanying diagram, Fig. 1, shows the thickness of plates on an enlarged scale and the depth below the top of the standpipe (equivalent to the depth of water) on a reduced scale. The series of stepped lines indicates the thickness and weight of plates proposed by the several bidders. The full line shows the design proposed by the Pittsburgh-Des Moines Steel Company, the low bidder to whom the contract was awarded.

The diagonal lines indicate the theoretical required thickness for an allowable tensile stress of 12 000 lb. per sq. in., and joint efficiencies of 100, 90, 80 and 70 per cent., respectively. While such a diagram cannot be relied upon solely in a study of the strength of the joints, it is of aid in indicating the location of the critical joints and in forming judgment as to the comparative value of the several bids.

TABLE 1.

GLOVERSVILLE, N. Y. WATER WORKS.

Comparison of Bids Received April 5, 1921 for Steel Standpipe (60 ft. diameter by 55 ft. high) and for Standpipe Foundation.

Name	Address	Days to Complete after Contract.	Price.	Estimated Weight, Lb.	Price per Lb. based on M & E estim'd Weights.
1. Pittsburgh-Des Moines Steel Co.	50 Church St., New York City	150	$24 940	331 000	7.5c
2. Tippett and Wood,	162 Howard St., Phillipsburg, N. J.	130*	25 990	300 000	8.7
3. Chicago Bridge and Iron Works,	30 Church Street, New York City	150†	26 700	325 000	8.2
4. Riter-Conley Co.	Pittsburgh, Pa.	150	29 170	300 000	9.7
5. Walch's Holyoke Steam Boiler Works	110 Appleton St., Holyoke, Mass.	150*	34 357	362 000	9.5
6. Dover Boiler Works,	50 Church St., New York City	150	36 220		
7. The Petroleum Iron Works Co., Inc.,	25 West 43rd St., New York City	200	39 825	348 000	11.4
Foundation (concrete) including substructure of valve chamber.					
Morrell Vrooman, Inc.‡	Gloversville, N. Y.	60	$5 662.12	Item 1	
			947 08	Item 2	
			$6 609.20	Total	
Walter Kidde & Co., Inc.,	140 Cedar St., New York City	45	$8 200.00	Item 1 — 45	
		15	1 100.00	Item 2 — 15	
			$9 300.00	Total	
A. E. Brace Construction Co.,	39 Hamilton St., Gloversville, N. Y.	90	$9 055.86	Item 1	
			696.00	Item 2	
			$9 751.86	Total	

Total for standpipe, excluding engineering:

Steelwork	$24 940	Contract price.
Foundation	6 609	Contract price = 26.5% of steelwork.
Total	$31 549	

* Working days. † Verbal. ‡ Awarded contract.

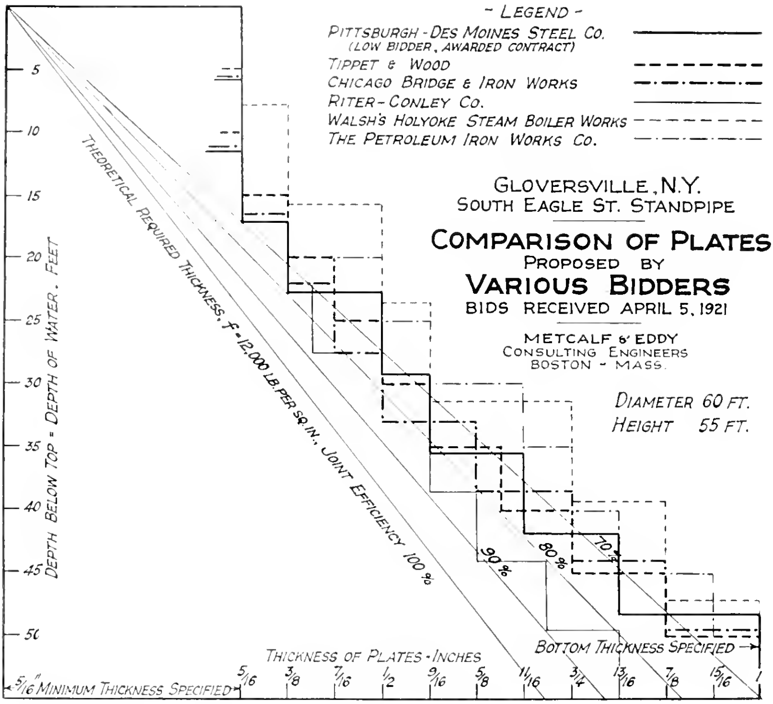


FIG. I.

STANDPIPE FOUNDATION.

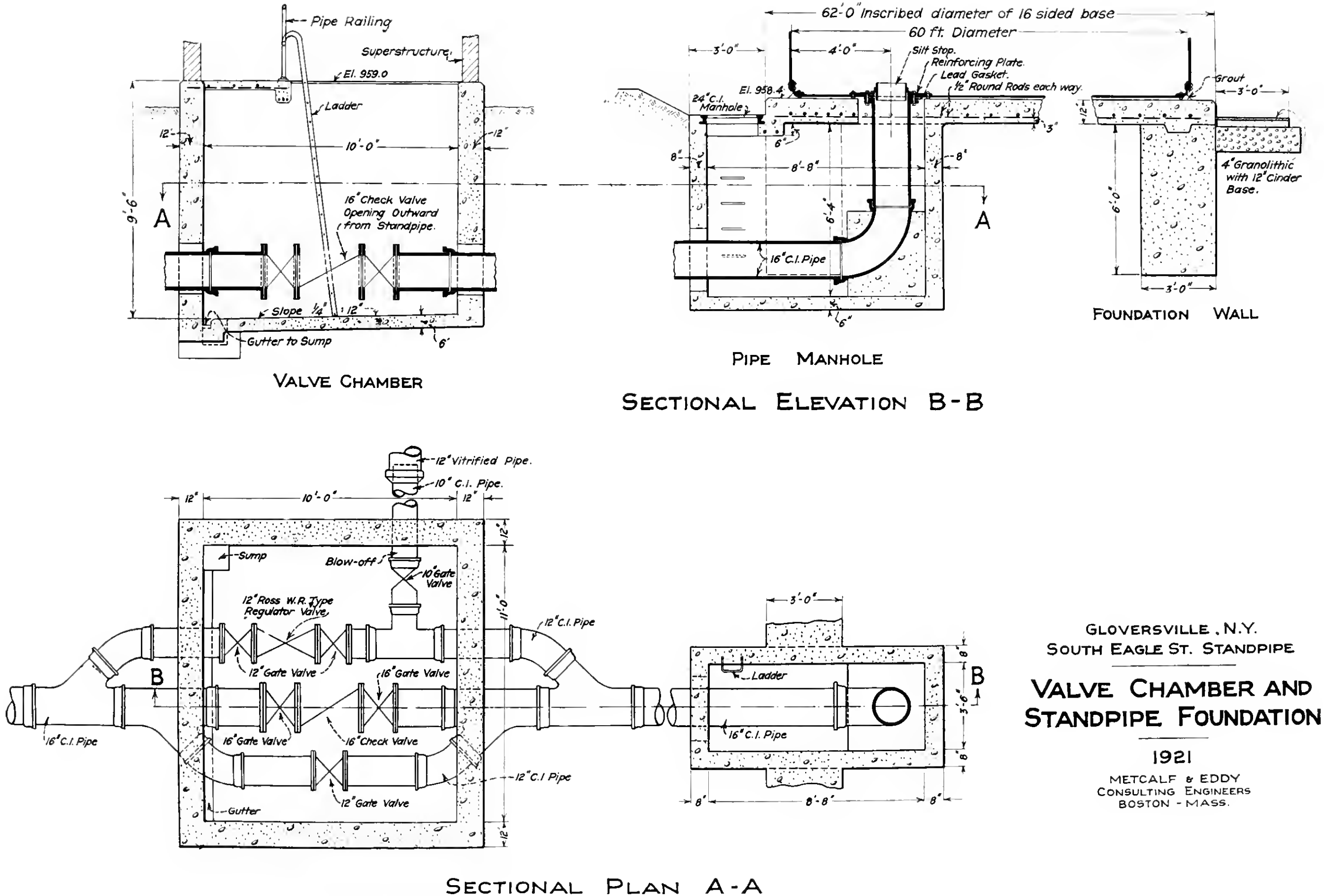
The drawings and specifications for the reinforced concrete standpipe foundation and the valve chamber substructure were also prepared by Metcalf & Eddy, and contract for the construction was awarded to Morrell Vrooman, Inc., of Gloversville, the lowest bidder. The principal details are shown in Fig. 2.

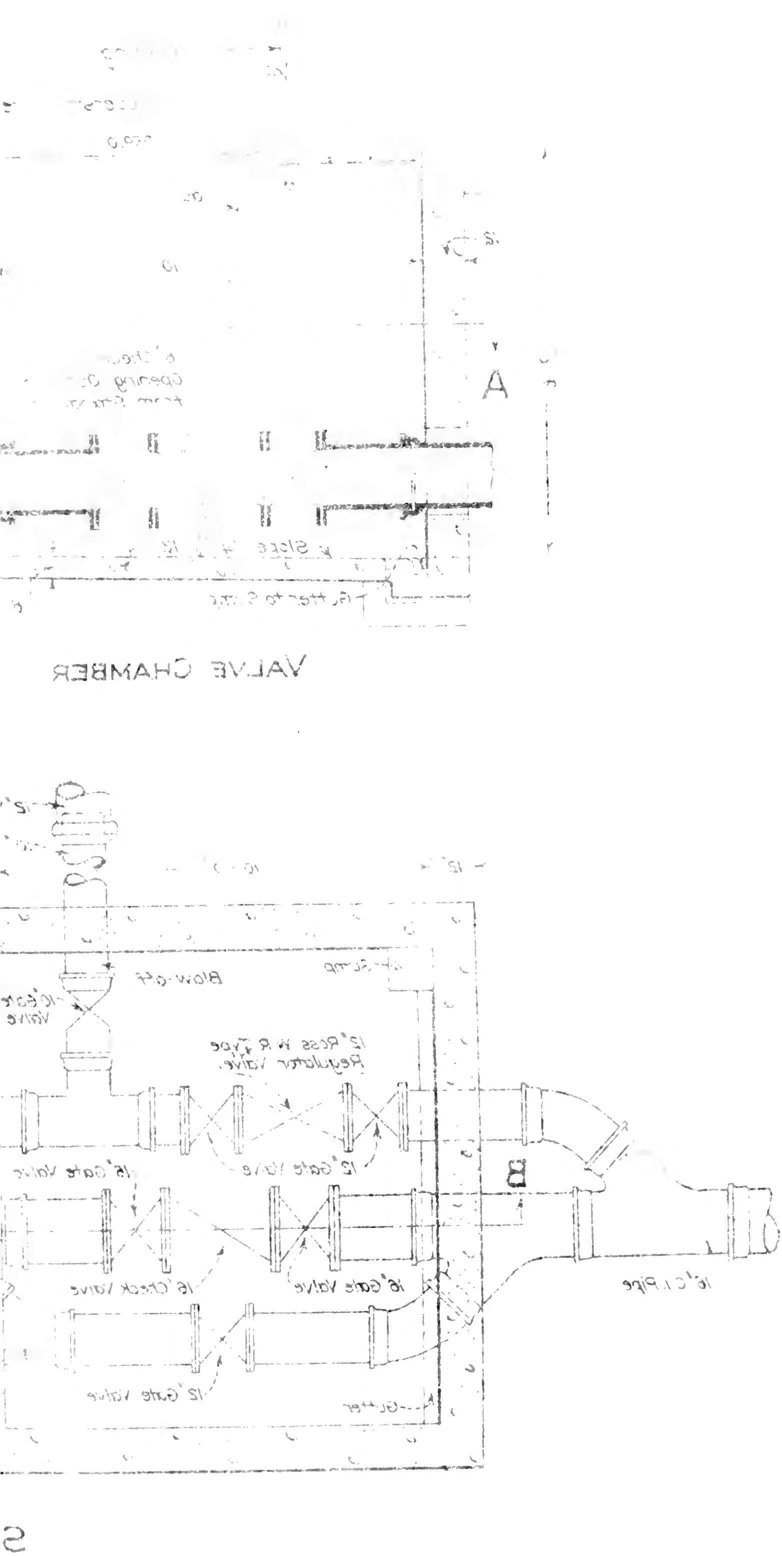
The foundation consists essentially of a circumferential wall of concrete, 3 ft. wide and about 7 ft. high, and is entirely in excavation, the only fill required being adjacent to the wall at the top, and very small in amount. The material excavated was such that no sheeting was required in excavating the trench for the foundation wall. No forms were used for the wall except the upper part on the exterior where they were necessary in order to obtain the desired finish.

The foundation slab, 12 in. in thickness, is reinforced with $\frac{1}{2}$-in. round deformed steel bars 12 in. on centers in two directions at right angles to each other.

Over the inlet pipe a small manhole is provided, affording access to the joint between the inlet pipe and the bottom plate of the standpipe.

FIG. 2.
N. E. W. W. ASSOCIATION.
VOL. XXXVI.
MARSTON ON
GLOVERSVILLE STANDPIPE.





Valve Chamber.

The valve chamber, a plan of which is shown in Fig. 2, houses the valves controlling the operation of the standpipe.

The inlet pipe is divided into three lines where it passes through the valve chamber. The first line contains a 12-in. Ross W-R type regulator valve, by means of which water is allowed to enter the standpipe up to a point a few feet below the top. When it attains this height the regulator valve will close, stopping the entrance of water and preventing overflow of the standpipe. A gate valve is provided on either side of the regulator valve, so that the latter can be removed without throwing the standpipe out of service. This line also contains a branch with a gate valve, to serve as a drain for emptying the standpipe.

The second line contains a 16-in. check valve arranged to open outward, allowing water to leave the standpipe, but preventing the entrance of water through this connection. A gate valve is provided on either side of the check valve to permit its being removed while the standpipe is in service.

The third line is a by-pass and contains a gate valve. In case of damage or interruption of service in either one of the other two lines the by-pass can be opened and the standpipe kept in service.

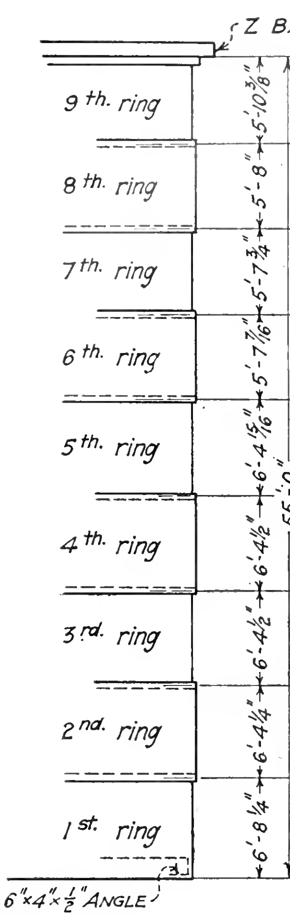
The piping and valves were furnished and installed by the Water Department.

The connection between the standpipe and the inlet pipe was made with a flanged-spigot cast-iron pipe. The flange was bolted to the reinforced steel bottom plate of the standpipe, and the spigot end was set into a bend with a lead joint, as shown on Fig. 2. The lead joint provides for a slight movement of the bottom of the standpipe without throwing undue strain on the inlet pipe. If there should prove to be frequent movement of the pipe tending to loosen the joint it can be caulked tight since it is conveniently accessible.

Provision has been made to retain the sediment in the standpipe and to prevent it from being washed into the outlet when water is drawn from the standpipe, by means of a silt stop built from a piece of 16-in. wrought iron pipe with 6 brackets made of $1\frac{1}{2}$in. by $1\frac{1}{2}$ in. by $\frac{1}{2}$ in. angles, each four inches long, riveted to the sides of the wrought iron pipe, and so located that the pipe will extend four inches above the floor of the standpipe. This is not fastened in place, but is sufficiently heavy to retain its position without being dislocated by the current of water.

Construction of Standpipe.

Bids for the construction of the steel standpipe were opened on April 5 and the contract with the Pittsburgh-Des Moines Steel Company was signed on April 8, 1921. It will be seen from Fig. 3, whereon the principal design details are given, that the tank is 55 ft. high and has nine courses



Ring	Height	PLATES: Length	PLATES: Width	PLATES: Thickness	PLATES: Number	STRAPS: Inside width	STRAPS: Outside width	STRAPS: Thickness	VERTICAL JOINTS: Rivets	VERTICAL JOINTS: Type	VERTICAL JOINTS: Pitch of outside row	VERTICAL JOINTS: Efficiency of joint
9th. ring	5'-10 3/8"	15'-8 13/16"	5'-11 3/4"	5/16"	12"	8 7/8"	4 5/16"	5/16"	5/8"	Double Riveted Butt	3 3/8"	77.4%
8th. ring	5'-8"	15'-9"	5'-11 3/4"	5/16"	12"	8 7/8"	4 5/16"	5/16"	5/8"	Double Riveted Butt	3 3/8"	77.4%
7th. ring	5'-7 3/4"	15'-8 13/16"	5'-11 3/4"	5/16"	12"	8 7/8"	4 5/16"	5/16"	5/8"	Double Riveted Butt	3 3/8"	75.9%
6th. ring	5'-7 7/16"	15'-9"	5'-11 3/4"	3/8"	12"	9 3/8"	4 5/8"	5/16"	3/4"	Double Riveted Butt	4"	78.4%
5th. ring	6'-4 15/16"	15'-8 3/4"	6'-9 3/4"	1/2"	12"	10 7/8"	5 7/16"	3/8"	7/8"	Triple Riveted Butt	4 5/8"	76.3%
4th. ring	6'-4 1/2"	15'-9 1/16"	6'-9 3/4"	9/16"	12"	15 1/4"	9 11/16"	3/8"	7/8"	Triple Riveted Butt	7.47"	81.0%
3rd. ring	6'-4 1/2"	15'-8 11/16"	6'-9 3/4"	11/16"	12"	15 1/4"	9 3/4"	1/2"	7/8"	Triple Riveted Butt	7.47"	79.0%
2nd. ring	6'-4 1/4"	15'-9 1/8"	6'-9 3/4"	13/16"	12"	17 1/4"	11"	9/16"	1"	Triple Riveted Butt	8.23"	79.2%
1st. ring	6'-8 1/4"	15'-8 5/8"	6'-10 3/4"	1"	12"	17 1/4"	10 3/4"	5/8"	1"	Triple Riveted Butt	6.8"	76.3%

CIRCUMF. JOINTS: Joint	Rivets	Type	Pitch (each row)
Top of 9th ring	5/8"	Single Riveted Lap	3.00"
9th–8th	5/8"	Double Riveted Lap	2.74"
8th–7th	5/8"	Double Riveted Lap	2.74"
7th–6th	3/4"	Double Riveted Lap	3.00"
6th–5th	3/4"	Double Riveted Lap	3.10"
5th–4th	7/8"	Double Riveted Lap	3.32"
4th–3rd	7/8"	Double Riveted Lap	3.32"
3rd–2nd	7/8"	Double Riveted Lap	3.43"
2nd–1st	1"	Double Riveted Lap	4.03"
Bottom of 1st ring	1"	Double Riveted Lap	4.02"

Bottom plates 3/8" thick, laid in courses about 6 ft. wide by from 16 ft. to 6 ft. long; single riveted joints lapped 2 1/4"; 3/4" rivets; pitch 2 1/4". All plates of "flange" steel. Joints calked inside on bottom and outside on sides. Standpipe sandblasted before painting. Manhole 18"×22" in bottom course. Outside ladder of 3/4" round rungs and 3"×3/8" side bars. Estimated total weight = 331,000 lbs. Laps, straps, angles, Z bars, ladder and rivet heads est. 16% of total. Capacity 1,163,000 gallons. Cost of standpipe, \$24,940 (= 7.5¢ per lb.) Cost of foundation \$6,609.20 Total = \$31,549.20 = \$27,150 ± per million gallons.

GLOVERSVILLE, N.Y.

SOUTH EAGLE ST. STANDPIPE

55 FT. HIGH × 60 FT. DIAMETER

DETAILED AND ERECTED BY

PITTSBURGH-DES MOINES STEEL CO.

METCALF & EDDY

CONSULTING ENGINEERS

BOSTON - MASS.

FIG. III.

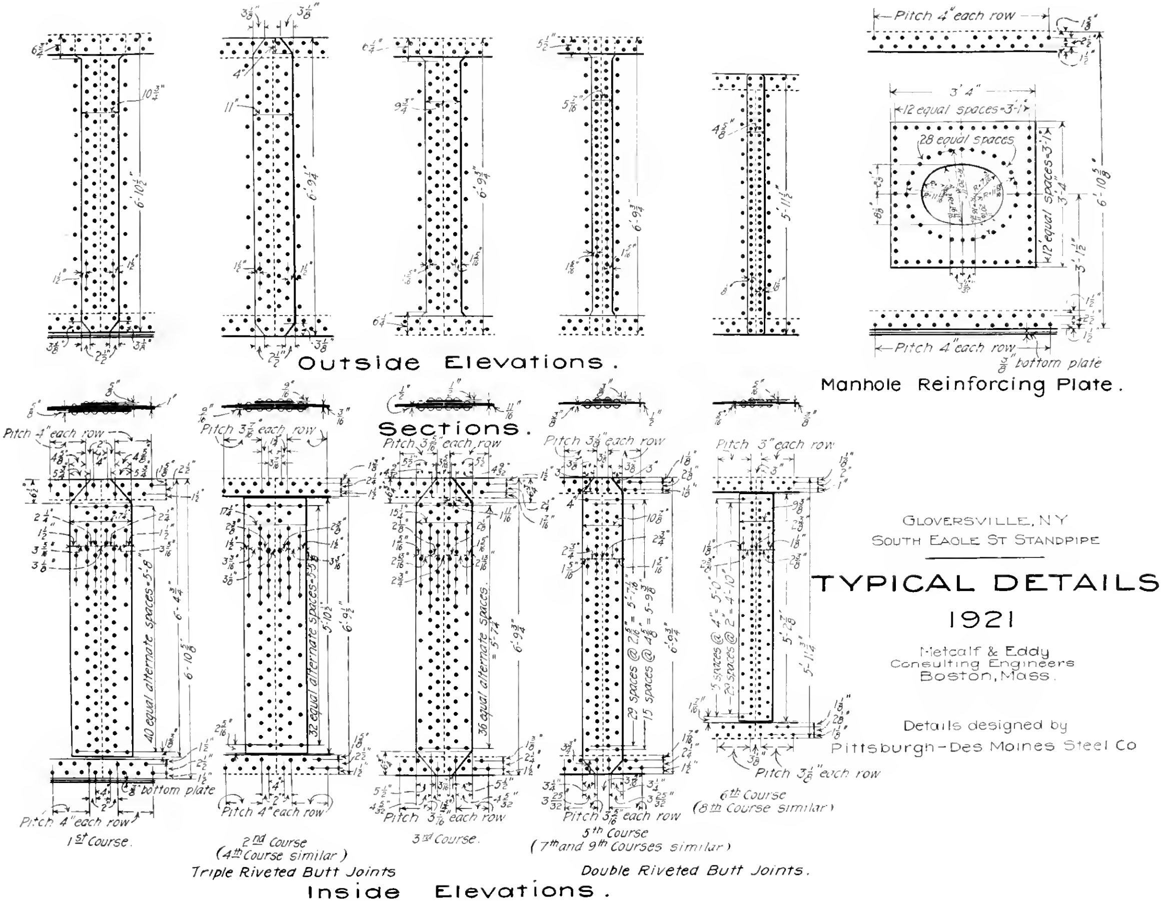
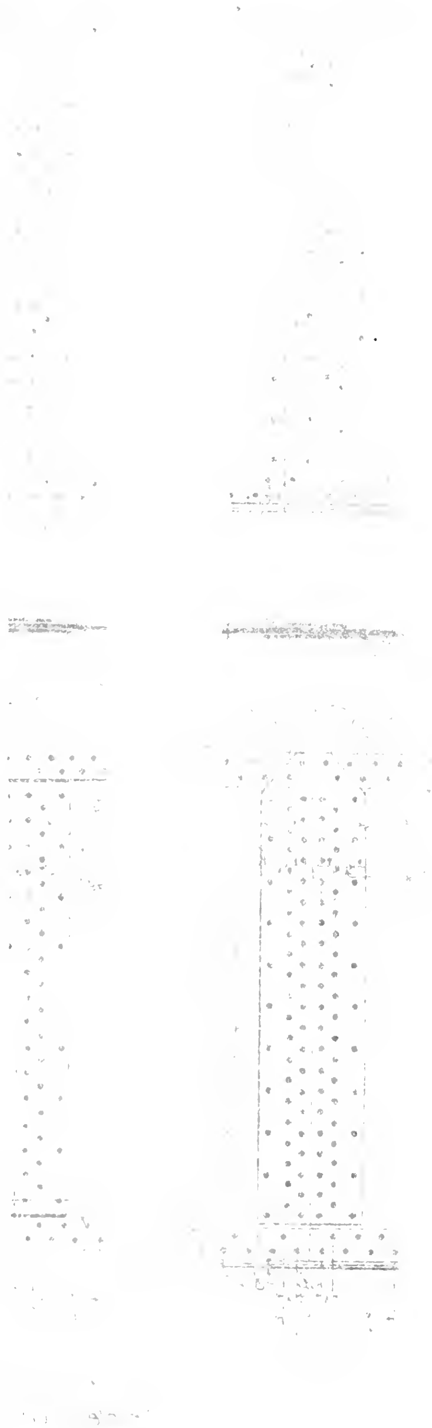


FIG. 4
N. E. W. W. ASSOCIATION.
VOL. XXXVI.
MARSTON ON
GLOVERSVILLE STANDPIPE



of 12 plates each, the plates varying in width from 6 ft. $10\frac{3}{4}$ in. to 5 ft. $11\frac{3}{4}$ in. and in thickness from 1 in. at the bottom to $\frac{5}{16}$ in. at the top. The rivets vary in diameter from 1 in. to $\frac{5}{8}$ in. Typical details are shown on Fig. 4.

After the reinforced concrete foundation had been completed the first shipment of steel plates was delivered (on June 21) and on July 2 the erection of the bottom plates began. They were assembled, riveted together, the angles attached to the circumference, and all joints caulked, with the bottom supported on wooden horses three feet above the concrete foundation. Four jack screws were then inserted to support the interior plates, and the wooden horses removed. The exterior or periphery

PLATE I.

of the bottom was supported on blocking in such a way that it could easily be lowered by removing one block at a time. This use of blocking, instead of jackscrews, around the edge, may at first thought seem objectionable, as it permitted the plates to sag as much as 4 in. between the blocks, as one after another of the blocks was removed. But as far as could be determined no damage to either plates or joints resulted.

The photograph (Plate I) indicates the general manner of lowering the blocking, one man operating each of the four jack screws and other men being located around the periphery of the bottom to remove the blocks. In this way the bottom was lowered on to the foundation within a period of about two hours, in a successful manner and without undue strain on any of the plates, the gang required consisting of one foreman, seven iron workers and three laborers.

The jack screws above referred to, passed through threaded flanges or nuts, riveted to the upper side of the bottom plates (see Plate II). These flanges were left in place and the threaded hole closed, upon removal of the jack screws, by means of a special screw plug. The lower ends of these jack screws were hemispherical in shape and rested on small steel pads

set on top of the concrete foundation. These pads, when the tank bottom had been lowered to within 18 in. of the foundation, were removed from under the jackscrews so that the latter rested directly upon the concrete. This resulted in some movement of the jack screws as the bottom was lowered further, and damaged the threads of the screws, but so far as could be determined resulted in no damage to the plates.

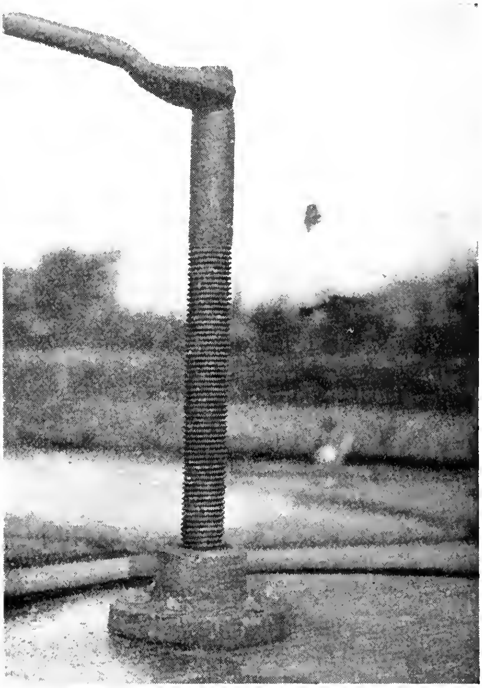


PLATE II.

With the exception of the bottom rivets, all of which were driven by pneumatic hammers, the riveting up to the sixth course was done by a compression riveter, or "gap riveter" as it is sometimes called. This equipment is shown in Plate III. The caulking was done with pneumatic caulking tools, using a round nosed chisel. Above the sixth course, pneumatic hammers were used as the plates were thinner and better progress could be made in that manner.

Stagings used during the riveting and caulking processes were supported by brackets bolted to the sides of the standpipe, for which provision had been made in the fabrication of the plates. The holes for the bracket supports were closed later by rivets. The type of staging used is illustrated in Fig. 6. The "dolly bars" use in bucking-up against the rivet head were swung from a rope or chain supported by the upper edge of the side plates. They weighed about 100 lb. each. For the riveting of the bottom

plates the dolly bars were supported by a so-called "bucking-up stool." This consisted of a plank, one end of which was inserted under the lower end of the vertical dolly bar, with a block on the under side of the plank to act as a fulcrum, and with the operator sitting on the other end of the plank, using it as a lever to force the dolly bar up against the rivet head.

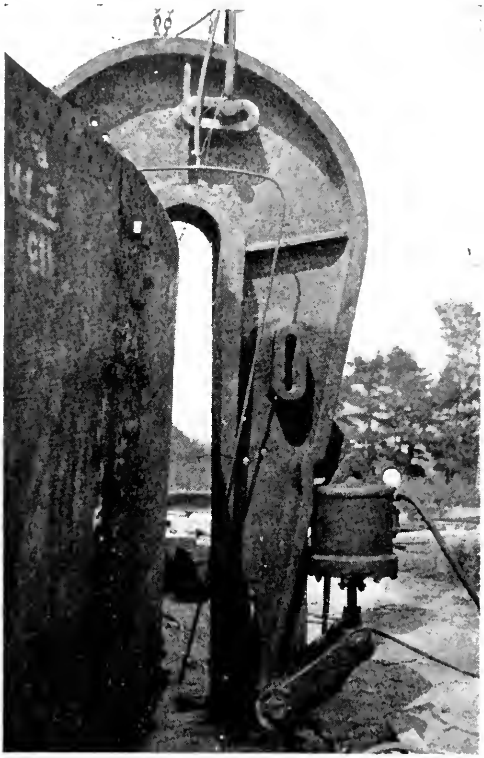


PLATE III.

For the erection of the side plates a structural steel, guyed derrick was used, the mast being about 90 ft. in length and the boom about 80 ft. This derrick was erected after the tank bottom had been lowered on to the concrete foundation. Its foot was supported on wooden blocking resting directly on the tank plates which in turn rested on the concrete underneath. The erection of the derrick was accomplished by the use of a 60-ft. gin pole made up of two 30 ft. 8 in. x 8 in. timbers spliced with 2-in. planks. After the erection of the standpipe and before sand blasting and painting were begun, the derrick and boom were dismantled and hoisted out piece by piece by means of the gin pole.

After the erection of the sixth course of side plates, but previous to the removal of the derrick, grouting operations were commenced, to fill the space between the tank bottom and the concrete foundation. The

grout was composed of a mixture of cement, sand, and water in the proportions of one part by volume of Portland cement to one part of fine sand, with only sufficient water to make the mixture flow freely.

Threaded flanges were provided in each of the plates forming the bottom of the standpipe, into which were inserted 2-in. wrought iron grouting pipes limited in length to 24 in., in order to avoid undue upward pressure upon the bottom plates. Through these grout was poured until the space between the bottom of the tank and the concrete foundation was filled as completely as possible. Some difficulty was experienced in filling

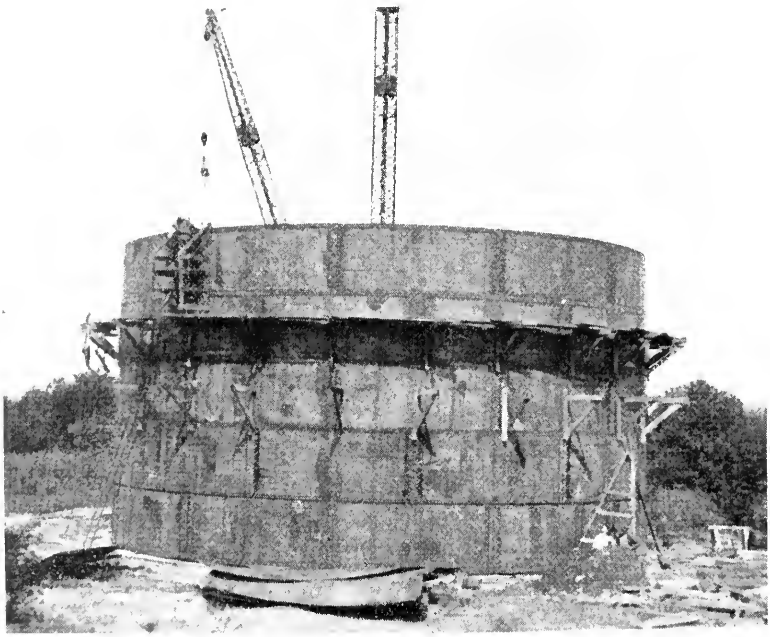


PLATE IV.

this space, because of buckling of the plates due in part to the grout pressure and partly to expansion from the heat of the sun. Some upward movement of the center plates may have occurred when the derrick was removed, so that it cannot be said that the grouting operation was entirely satisfactory. It is believed to be somewhat more satisfactory than the sand-cement cushion method of bedding the bottom plates. Neither method seems to give ideal results, although both methods have been used successfully. It is anticipated, however, that with water in the tank a fairly uniform pressure of the structure on the grouted foundation will be obtained. Upon completion of the grouting the grout pipes were removed and the threaded flange holes closed with screw plugs.

In the erection of the plates very little work was required to fair the holes, — that is, to make the holes match. While drift pins were used to

a slight extent and in an unobjectionable manner, it may be said, in fairness to the contractor, that the layout of the plates was unusually good. Practically all of the holes were reamed after the plates were set in place, to ensure a good surface for bearing against the rivets.

The small openings left in the top and bottom of each vertical butt joint were closed by driving in steel wedges or "dutchmen" and by caulking over the top of the wedge.

The specifications required that the plates should be given one coat of boiled linseed oil, before leaving the shop. The contractor, however, was allowed to omit the oiling of the plates except on the laps, since it was believed that the slight rusting which would occur in the body of the plate would aid in softening the mill scale and facilitate the sand blasting. Very little rust formed on the plates before they were painted, so it was difficult to determine whether the omission of the oiling aided the sand blasting or not.

Sand Blasting.

Before the first coat of paint was applied the surface of each plate was thoroughly cleaned with the sand blast, using a local sand which was discharged through a nozzle with air pressure from a sand atomizer. By this means all loose scale and rust were removed. The first coat of paint was applied immediately after the sand blasting had been completed and before the cleaned surface had an opportunity to rust. Both sand blasting and painting were done from a staging suspended from trolleys supported by the Z-bar attached to the top of the tank.

Painting.

The inside and outside of the standpipe were given three coats of paint mixed according to the following formulæ:

For interior of standpipe:

First coat — 100 pounds paste red lead, 2 gallons pure boiled linseed oil, 8 pounds fine litharge mixed in 1 pint raw linseed oil and 1 quart turpentine.

Second coat — Same as above, with the addition of ¾ pound of paste lamp black.

Third coat — 100 pounds paste red lead, 4 pounds paste lamp black, 2.25 gallons boiled linseed oil, 8 pounds fine litharge mixed in 1 pint raw linseed oil and 1 quart turpentine.

For exterior of standpipe:

First coat — 100 pounds paste red lead, 2.5 gallons raw linseed oil, 1.5 pints turpentine, 1.5 pints drier.

Second coat — Same as above with the addition of ¾ pounds of paste lamp black.

Third coat — (Dark green) 100 pounds paste red lead 12½ pounds paste chrome yellow, medium, 7½ pounds paste Prussian blue 1.51 gallons of raw linseed oil, 1 pint turpentine, 1 pint drier.

Paint materials were received on the work in the original packages and mixed at the site of the work. During the painting operations one man was continuously employed in keeping the paint in the stock barrel thoroughly mixed.

Both sand blasting and painting were done by the iron workers who erected the tank.

TABLE 2.

PROGRESS DATA.

	Date 1921.	Elapsed Time.
STANDPIPE:		
Asked for bids	March 1	
		35 days
Opened bids	April 5	
		3 days
Contract signed†	April 8	
		29 days
Shop drawings received	May 7	
		7 days
(Steel received at shop about	May 12)	
Shop drawings approved*	May 14	
		38 days
First steel shipment arrived	June 21	
		11 days
Erection started	July 2	
		19 days
Bottom lowered	July 21	
		34 days
Erection completed	Aug. 24	
		23 days
Sand blasting and painting completed	Sept. 16	
Total time from signing of contract		161 days
(Contract agreement		150 days)
FOUNDATION:		
Asked for bids	March 1	
		35 days
Opened bids	April 5	
		3 days
Contract signed	April 8	
		25 days
Ground broken	May 3	
		3 days
Concreting started	May 6	
		14 days
Foundation completed**	May 20	
Total time from signing of contract		42 days
(Contract required completion of this part of the work on or before June 1, 1921.)		

† Steel ordered soon after.

* Fabrication started soon after this.

** Except for grading and granolithic walk, which were completed after standpipe was erected.

Testing.

After the erection had been completed the tank was filled with water, for testing. The amount of leakage was found to be very slight, which fact reflects much credit upon the thorough manner in which the erection work was performed. A few seams required a little caulking and a few rivets which showed small leaks were touched up with the caulking tool. One rivet which was broken was cut out and replaced.

The time required for the various parts of the work are indicated in the progress table (Table 2). It will be noticed that the total time required for completing the steel standpipe contract, including sand blasting and painting, from the date on which the contract was signed, was 161 days. The time limit specified in the contract was 150 days. A delay of several days was caused by breakdown of the air compressing plant.

Cost of Standpipe.

The cost of the standpipe, classified under certain general headings, is given in Table 3. The total cost of the structure, including foundations, sand blasting and painting, valve chamber and piping, but excluding engineering, administration, cost of land and fencing, is \$35 015.80, equivalent to \$30 000 per million gal. of capacity. The fencing, constructed by the Cyclone Fence Company, 8 ft. in height with three strands of barbed wire on the top, cost about \$1.55 per linear foot, erected. This sum includes two swinging gates. The above cost figures do not include the cost of the small trees, which were set out by the Water Department. These were obtained from the nursery maintained by the Department, which for a number of years has made a practice of systematic planting on the watersheds and other lands in its charge. In this and other ways Mr. Orr has shown wise management in the handling of many perplexing problems in connection with the operation of the water works.

It is a pleasure to commend the conscientious manner in which the construction of this structure was supervised by the resident engineer, Mr. Fred W. Carlson, to whom the writer is indebted for much of the information relating to the construction work.

The work of the contractor, also, deserves commendation, as it was evident from the start that not only those in authority in the company, but also the erecting crew, intended to do first-class work in strict accordance with the specifications. The shearing of the plates, the alignment of the joints, the forming of the rivet heads, the caulking and all of the mechanical operations, were extremely well done.

TABLE 3.

GLOVERSVILLE, N. Y.

COST OF SOUTH EAGLE STREET STANDPIPE, FOUNDATION, AND CONNECTION WITH MAINS. BUILT IN THE SUMMER OF 1921.

Tot. wt. 331,000 lb.; equiv. cost per lb. 7.5c.

Standpipe contract (Pittsburgh-Des Moines Steel Co.)		$24 940.00
Foundation, gate chamber, 12″ vitrified pipe, blow-off and grading		6 609.20
Castings:		
4 16″ x 12″ Y br., 3 877 lbs. @ .08½	$329.55	
1 12″ x 10″ tee, 540 lbs.		
1 16″ 90° bend, 760 lbs.		
4 12″ 45° bend, 2416 lbs. @ .07½	181.20	
1 16″ F & S p. 4 feet, 4 inches, 815 lbs., @ .09¼	75.39	
2 16″ F & S p. 24 inches, 651 lbs.,@ .10¼	66.73	775.48
2 12″ F & S p. 3 feet, 540 lbs. @ .10¼	55.35	
1 12″ F & S p. 2 feet, 7 inches, 262 lbs. @ .10¼	26.86	
1 12″ F & S p. 12 inches, 121 lbs. @ .10¼	12.40	
Manhole casting and cover	16.00	
Gate box casting	12.00	
Gate valves, etc.:		
2 16″ flg. gates @ 153.00	306.00	
3 12″ flg. gates @ 81.00	243.00	
1 10″ h & s gate	60.00	1 305.62
1 16″ ck. valve	143.10	
1 16″ hub gate	143.00	
1 12″ Ross altd valve	410.52	
Connecting gate chamber with main in street and gate chamber with standpipe		
36′ 16″ c. i. p., 3 900 lbs. @ 64.00	$124.80	
1 16″ sleeve, 280 lbs. @ .07½	21.00	180.40
692 lbs. lead @ .05	34.60	
Labor account, $107.50, $144.00, $69.00		320.50
Freights		34.60
Gate House (of tapestry brick with raked joints, 11′ 4″ x 12′ 4″ plan, by about 10′ high (approx. $0.60 per c.f.)		850.00
Capacity of Standpipe 1 163 000 gal.		
Total cost per m.g. excl. eng'g., administration, land and fencing		30 000.00
Total cost		$35 015.80

DISCUSSION.

MR. A. O. DOANE.* The Metropolitan District Commission has just awarded a contract for a steel tank to be built at Arlington Heights which will be 61 ft. high and 75 ft. in diameter. We have had several stand pipes built since the work commenced, and have tried various methods of designing. In the previous ones the policy had been of designing the standpipe complete; that is, giving the size and location of the rivets and all other details.

In this particular instance we have done very much the same as Metcalf & Eddy, the difference being simply in the matter of detail rather than in the matter of principle, largely from the same considerations that Mr. Marston mentioned, of allowing a reasonable and proper latitude to

* Division Engineer Metropolitan Water Works.

the contractor in selecting his height of plates and in the general detail of carrying on the work, and at the same time making sure that the standpipe will have the desired strength.

In this case, instead of specifying a maximum allowable stress of 12 000 lbs. per sq. in. of net section in the steel plates, we have given a net formula which takes into consideration the efficiency of the joints, — the joint to be designed by the contractor with certain limitations and checked up by the engineer. In the case of any of the vertical joints the strength of the joint must be at least $4\frac{1}{2}$ times as great as the bursting pressure at the bottom of the joint. It was specified that all joints should be of the butt type, with inner and outer cover plates; but there was no limitation made as to the number of rows of rivets in the vertical joints. It was also specified that no matter how the formula worked out, no side plate should be less than $\frac{3}{8}$ in. in thickness. The bottom plates of the standpipe must be not less than $\frac{3}{8}$ in. in thickness. The general detail of the standpipe was not very much different from the one shown here, except that the circumferential seams were single instead of double riveted.

The bids that we received seemed to show that there was a pretty general agreement amongst the bidders in the matter of the thickness of plates proposed in the different bids. The efficiency of the joints proposed by the successful bidder was checked over and found to be correct.

The specifications provided that the water pressure governing the designs of any course of side plate should be taken at the bottom of the course. The depth of water assumed to be in the tank, and the pressure per foot in depth, were also given.

The principal point of difference between the specifications that Mr. Marston mentioned and the Metropolitan specifications was in following the provisions of the boiler rules rather than the structural practice of giving the allowable stresses. As no construction work has been done we cannot tell exactly how this method of specifying will work out, but from the way the bids were received and the general agreement amongst different bidders it seems to have worked out pretty well in this particular instance; and it has the advantage that Mr. Marston mentioned of probably producing a somewhat less cost than if we tried to go into minute detail and tying the contractor up in all sorts of ways, though that is impossible to tell, especially under the present conditions of business when many contractors seem willing to sacrifice profits in order to keep their works running.

Mr. Charles W. Sherman.* What were the bids, Mr. Doane? What was the accepted bid?

Mr. Doane. There were eight bids ranging from \$29 737 to \$49 820; the price bid included taking down and disposing of an existing standpipe, 60 ft. high and 40 ft. in diameter.

Mr. Sherman. How does that work out on the pound basis, — do you know?

* Of Metcalf & Eddy, Boston, Mass.

MR. DOANE. It is almost exactly five cents a pound for the lowest bidder.

MR. SHERMAN. Is that standpipe to be enclosed in a tower?

MR. DOANE. Yes, the standpipe is to be enclosed in a masonry tower, so that we were not so much concerned with the effect of severe weather and severe winds, though from our experience with other tanks and from other people's experience, we feel that the tank is so constructed that it will take a violent wind to effect it. The capacity is about 2 000 000 gallons.

We also plan to have the tank in this case lowered onto a sand and cement cushion instead of using the grouting process. I have personally tried both ways and I rather lean to the sand and cement method, though each has its advantages and very decided disadvantages. I do not think there is any entirely satisfactory way of supporting the bottom plates on the foundation.

MR. G. A. SAMPSON.* What was the price on the Gloversville and East Chicago standpipes for sand blasting and painting?

MR. MARSTON. The Gloversville was $7\frac{1}{2}$ cents per pound, including sand blasting and painting; the East Chicago was $6\frac{1}{2}$ cents including sand blasting and painting. I think Mr. Doane said 5 cents a pound did not include sand blasting and painting.

MR. DOANE. No, that does not include sand blasting and painting, but I think the sand blasting and painting would be around a half cent or a little more.

MR. REEVES J. NEWSOM.† How long is it expected that the paint will last?

MR. DOANE. I can perhaps throw some light on that. From our experience with painting that has been thoroughly done, I should say it ought to last five or six years anyway, and does actually last that. A smaller tank that I know of, which has one layer of Gilsonite paint over the red lead, and is enclosed in a building, was painted ten years ago and it is not at all in bad shape now. Ice, of course, makes a great deal of difference, — also exposure to the weather. If you have ice going up and down it will scrape any kind of paint off.

* Of Weston & Sampson, Boston, Mass.

† Water Commissioner, Lynn, Mass.

RELATIVE TO THE REPORT OF THE AMERICAN COMMITTEE ON ELECTROLYSIS

The American Committee on Electrolysis has just issued its 1921 report, superseding its preliminary report of 1916. This report embodies such statements of facts and descriptions, and discussions of methods of electrolysis testing and electrolysis mitigation as the members of the committee have been able thus far to agree upon unanimously. In the preface, signed by Bion J. Arnold, Chairman of the Committee, the following statement is made:

"While this report supersedes the preliminary report of 1916, it should, unless the principals see fit to discontinue the work of the main committee, be considered as in the nature of a progress report and not as final, as it is impossible at the present time to answer finally many of the outstanding questions involved. Also it is to be understood that the report is confined to the technical and engineering aspects of the subject and does not attempt to deal with matters of policy or with legal questions, such as the rights and responsibilities of the several interests concerned."

The report comprises five chapters. Chapter One sets forth principles and definitions. Chapter Two is devoted to a detailed discussion of design, construction, operation, and maintenance of railways and underground structures affected by electrolysis, and to a discussion of questions involving the interconnection of affected structures and railways, ending with a summary of good practice. Chapter Three gives a discussion of the fundamentals of the whole question of electrolysis surveys, their purpose, scope, possibilities and interpretation, and also a discussion of the instruments suitable for electrolysis testing. Chapter Four is devoted to an analysis of present European practice relating to electrolysis mitigation. In Chapter Five the committee outlines certain researches which it deems necessary to have carried out in order to make it possible to reach a final solution of some of the fundamental questions pertaining to electrolysis mitigation.

The American Committee on Electrolysis which prepared this report is a joint committee having three representatives from each of the following organizations:

American Institute of Electrical Engineers.
American Electric Railway Association.
American Gas Association.
American Railway Engineering Association.
American Telephone and Telegraph Company
American Water Works Association.

National Electric Light Association.
Natural Gas Association of America.
National Bureau of Standards.

Arrangements have been made for placing this report on sale by the American Institute of Electrical Engineers, 33 West 39th Street, New York, N. Y. The price is one dollar per copy.

November 25, 1921.

(This statement forwarded by ALFRED D. FLINN, a representative of American Water Works Association.)

CEMENT JOINTS FOR CAST-IRON WATER MAINS.

D. D. CLARKE*

(By letter.)

In the JOURNAL for March, 1922, under the heading "Pipe Joint Compounds," there appears a discussion which took place September 14, 1921 upon the relative merits of the compounds called leadite, — hydrotite etc., participated in by a number of water works superintendents and engineers.

Without exception the speakers confined their remarks to their experience in the use of leadite or hydro-tite as a substitute for the poured lead joint for cast-iron pipe, long in customary use.

In no case, however, was mention made of the use of cement as a substitute for lead in its various forms or combinations, and it therefore occurs to the writer that a statement of the experience of the Portland, Oregon Water Department in the caulking of water-pipe joints with cement might make an interesting addition to the discussion.

Prior to the year 1915, poured lead joints were the only kind in general use for cast-iron water mains in this city. Lead wool had been used to a limited extent for under water work, and leadite had been experimented with in a small way; but the poured lead joint was the main dependence for pipe-joint work. In December of that year, 1915, there came to the notice of the writer, then engineer of the Water Bureau, articles in the *Engineering News* — (November 25 and December 30, 1915) calling attention to the experience of Wm. Mulholland, Chief Engineer of the Bureau of Water Works of Los Angeles, Calif., in the use of cement for cast-iron pipe joints in that city. Mr. Mulholland in his letter called attention to the issue of the *News* for December 8, 1904, which contained a letter from the late James D. Schuyler, Consulting Engineer of Los Angeles upon the same subject.

An examination of these papers, and the favorable results secured at Los Angeles, caused the writer to recommend the adoption of similar materials and methods in this city. First, the laying of an experimental line of 1 000 ft. of 8-in. pipe, which proved to be so successful that other lines speedily followed until at the present time, as I am informed by Chief Engineer F. W. Randlett of the Water Bureau, practically no other caulking material than cement is used, except in special cases where the main must be put into use before the expiration of the 48-hour period necessary for the proper setting of the cement joint.

* Consulting Water Supply Engineer, Portland, Ore.

The method of preparing the cement and filling the joint adopted here is practically the same as that used in Los Angeles, viz., First quality medium setting cement is used, mixed so dry that the impress of the hand will be left upon a small ball which will crumble when let fall from the height of twelve inches. The pipe should be laid upon a firm foundation; the spacing of the spigot in the bell may be effected by placing a small bit of lead under it. A small bit of yarn should be used, just sufficient to keep the cement from entering the pipe. After filling the bell with cement it is thoroughly compacted with a yarning iron, by hand. This will have to be repeated two or three times before the face of the joint can be properly smoothed and rounded.

To the present time there have been laid in this city approximately 27.8 miles of 4-in., 6-in., 8-in., 10-in., 12-in., and 16-in. pipe with cement joints. In addition to the foregoing, approximately 4 000 ft. of 24-in. and 30-in. pipe has been taken up and relaid with cement joints during the progress of "grade crossing" elimination work.

When the first line of 8-in. pipe was laid in 1916, minute leaks occurred which were entirely taken up in a few weeks time. In relaying the 30-in. pipe mentioned above it was placed in a concrete lined tunnel which afforded an opportunity of observing the leakage. When the pressure was turned on the 500 or more feet of 30-in. pipe in the tunnel section, the leakage was very considerable. After draining the water from the tunnel two or three times the leakage was noticed to be decreasing and at the end of six months had stopped entirely and all the joints have since remained tight.

At a later date it became necessary to raise 100 ft. of 16-in. pipe which had been laid with cement joints. This pipe was raised approximately 4 ft. under full working pressure of about 70 lb. without any leaks resulting.

Prior to the general use of cement as a jointing material, as indicated above, the Department instituted a series of tests to determine the degree of flexibility in the joints of cast-iron pipe when laid with joints of neat cement, leadite or pig lead. These tests were described by Mr. Randlett in a contribution to the discussion of a paper upon "Cement Joints for Cast-Iron Water Mains", by Clark H. Shaw, Associate Member American Society of Civil Engineers, printed in *Transactions American Society of Civil Engineers*, Vol. 83, page 277. Mr. Randlett concludes from these tests, "that for all ordinary mains cement joints are superior to either lead or leadite," and his later experience has confirmed this opinion.

PROCEEDINGS.

February Meeting.

Boston City Club,

Boston, February 14, 1922.

The President, Mr. Frank A. Barbour, in the chair.

Karl R. Kennison, civil and hydraulic engineer, Boston, F. W. Scheidenhelm, hydraulic engineer, New York City, and Egbert D. Case, hydraulic engineer, New York City, were duly elected members of the Association.

The President. I recognize that this large audience has come out for a definite purpose, to hear the speaker of the afternoon, Mr. Goodnough. We have, however, a matter of some importance which it is necessary to bring to your attention. With the notice of this meeting the prospectus of the proposed Affiliation of Technical Societies was sent out to you. This proposed Affiliation is the result of a long series of informal meetings by representatives of different societies. It has reached the point now where the local sections of the American Institute of Electrical Engineers, the American Society of Mechanical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Heating and Ventilating Engineers, and the American Association of Engineers, have voted in favor of this Affiliation. The matter comes up to the Boston Society of Engineers to-morrow night.

It has been contemplated from the beginning that the New England Water Works Association would become a member of this Affiliation. Some weeks ago your Executive Committee voted in favor of the principle. That did not commit the Society; it only gave us grounds for going forward with the movement.

The scheme is that an affiliation of societies shall be formed — not of individual members, but a grouping of societies; that this Affiliation will take over the present headquarters of the Boston Society of Engineers; that the Affiliation will be governed by councillors, two elected from each Society. If the New England Water Works Association joins there will be two councillors elected from this body who will sit on this council which has the control of the Affiliation. It is proposed that they shall take over the premises of the Boston Society, that they shall install a permanent secretary, that that secretary shall have secretarial assistants, one of whom

will probably be the present assistant secretary of the New England Water Works Association. This movement has nothing to do whatever with the identity of this Association. We go forward with our own work just as we are doing to-day; it is merely a grouping of societies for headquarters purposes.

This movement has been the result of some twenty years of dreaming. When the Engineers' Club was started it was hoped that it might be founded by a group of technical societies. We have sometimes thought we would have a building of our own or we would take the upper floor of some building under construction. This movement is based on taking what we have got — the headquarters of the Boston Society, and starting with that, with the hope that it will lead to something bigger in the very near future. There is reason to expect that the membership will run up to three thousand at the very beginning and there is a possibility of five thousand sooner or later.

At the meeting of the Executive Committee this morning the following vote was passed:

"Voted:—That the Executive Committee recommend that The New England Water Works Association approve the purpose and general provisions of the Constitution of the Affiliation of Technical Societies of Boston submitted with the notice of the meeting of February 14, 1922, and that the Executive Committee be directed to appoint a suitable committee to represent the Association empowered to consummate the formation of said Affiliation, to prepare the constitution and by-laws, and to negotiate the necessary working agreement to govern the relations, rights and obligations of the Affiliation and The New England Water Works Association."

With this brief introduction, gentlemen, the subject is open for discussion.

Mr. Leonard Metcalf. Mr. President, I have a resolution that I would like to offer at this time, which was prepared by Mr. Sherman and myself, which would put into effect the idea which Mr. Barbour has so clearly outlined to you. I will read the motion first, and then I would like to say just a word in support of it, if I may, without taking much of your time:

"Whereas, a committee of representatives of various technical societies, or sections of societies in greater Boston having an aggregate membership of over 3 500, have outlined a plan for an alliance under the name of The Affiliated Technical Societies of Boston, and

"Whereas, closer coöperation between technically trained men in the water works and engineering fields is desirable, to make more effective their influence in public matters, to broaden information, interest, and acquaintanceship; and

"Whereas, the past advantages obtained by coördination of effort, avoidance of duplication, maintenance of a common headquarters, etc., have been of much value to this Association; and

"WHEREAS, the proposed affiliation is in effect a further extension of the coöperation that has obtained for many years between this Association and the Boston Society of Civil Engineers: now, therefore,

"BE IT RESOLVED, that the New England Water Works Association approves the purpose and principle of the proposed affiliation and authorizes its Executive Committee to determine after careful investigation whether or not this Association shall join said affiliation, and if the decision shall be favorable, to appoint two representatives of this Association with power to act for this Association upon the Council or other representative body of the affiliation."

The war has served to bring home to engineers and to men such as are here to-day the country over — the water works men, the electric light men, the gas men and men in public utilities generally, technically trained men in general — that they might exercise a much larger influence for the public good if they were more closely tied together. We have felt that need in this city ourselves within the last year or two in certain measures that have come before the Legislature that seemed unwise legislation to water works men. It would have been helpful at that time if we could on short notice have called together technically trained men who would see the point at issue quickly and could have helped to formulate public opinion. This measure would help in just that sort of contingency. The plan has been tried out in a number of cities in this country — in Philadelphia, in Chicago, where during the war it was of tremendous advantage to the government; in Los Angeles and in many other cities it has worked well. In some cases it has been developed in a way to make possible certain club features, making it possible to have dinners in advance of the meeting. In other cases it has been simply a tying together of the various organizitions. There is the further fact, faced not only by associations of this sort but by small clubs, the country over, that expenses have increased so enormously that they have become very burdensome, and it looks almost as if many of our small societies and clubs were doomed. The only method of meeting the difficulty seems to be in some form of coöperation or consolidation. Now this organization has been set up on a basis of coöperation rather than consolidation, with the belief that while these different groups, such as this one, will prefer to continue to get together as a group, they may yet enjoy the advantage of combination and may occasionally like to get together with the other groups with a view to broadening acquaintanceship. The Boston Society of Civil Engineers faces this year a deficit of over $2 000. Its expenses to-day and next year will be greater, not only than its income under present dues, but than its income plus the income on its permanent fund; therefore it means a curtailment of activities involving financial support in order to meet the situation unless some such plan can be adopted.

This organization has felt the financial burdens. Therefore it seems the sensible thing to do — it has seemed so to many men the country over — to get together in such a way as this, so that the cost of maintaining the

necessary facilities that we all want will be reduced to a minimum, so that our power for good may increase without loss in identity of the organization or indeed of its independence. The effect upon the dues, I think, will not be material. Whether it will involve a little increase at first or not, I am not sure. I think it may involve a slight increase, but it will be small. It may well be possible to carry it without any increase. Within a few years I have no question that it will involve either a decrease or a very distinct improvement in the facilities open to members. I am confident that looking forward for a longer period of years, we shall find it possible with a larger group of four or five or six thousand members to have joint facilities such as are enjoyed in this club, — I won't say on so large a scale, but I mean, where men of our interest can get together and do their work satisfactorily and cheaply. Therefore it seems to me that it is highly desirable that this association should join with others in making possible the saving of expense to all of the organizations and in giving greater influence to the work which engineers may undertake. I see no serious disadvantages; I see very distinct possibilities in the movement, and therefore I hope it will prevail. I thank you for your attention.

Mr. David A. Heffernan. There is one thing which as a member of the Executive Committee and a superintendent I wish Mr. Metcalf would make a little clearer. This proposition will probably be misjudged on the part of some of the superintendents, who may feel that it involves losing the identity of the New England Water Works Association. This Association was formed years ago by superintendents. Now the superintendents here to-day might possibly misconstrue this matter, and if Mr. Metcalf would go into it from the superintendents' point of view to impress them that there will be no material change, I think they will go away better satisfied.

Mr. Metcalf. Mr. President, I am very glad to say a word along that line. As I see the movement, the intention of the movement and what I believe will result, it makes absolutely no change in this organization in your methods of doing business except as to detail, or in the way in which you will run this Society. We should have, as we have to-day, headquarters. We should have at those headquarters probably a managing secretary who will take care of the work of the Affiliation. That secretary will send out the notices upon request of the secretary of any one of these societies, so that the clerical force of the Affiliation may do certain detailed work. The library facilities will be maintained in common as they are to-day. They will be bettered by the fact that other organizations than our own will add their libraries to our library. An employment bureau will be run for the Affiliation for the benefit of all concerned — not this group or the Mechanicals or the Civils, but of all men. That is the cheapest way to do it. The elections of this Society and the procedure in regard to all business matters will be just as independent undert he future conditions as to-day. It would merely mean that we would have a central council to which we

would make appeal when questions of importance to water works men were to come up before the Legislature or elsewhere and the assistance of the Affiliation as a whole through its Council would be invoked at those times. On matters touching the public good as to which we could advise with advantage to the public, that advice would be given again through the Council through our representatives on the Council, who would take part in its deliberations and be the direct agency by which that work would be done. So that as I see it you sacrifice nothing in your independence; the Society, I should hope and of course I believe, will continue to be run by water works men, by superintendents, not by the engineers. No one organization will run the Affiliation; no group of men will run the Affiliation. The central organization does the work simply for the public good and the essential business that we all want to get rid of. The individual work of the individual society will still be run by its own officers. The individual societies will still have their presidents, their secretaries, whatever staff they wish to maintain independent of the Affiliation. But it is only in those matters as to which economy can be effected by joint use, by joint publications and so on, that we expect to benefit.

Now a word in regard to publication. At the present time, as far as the understanding has gone, it has been that all of these societies would save expense in publication of notices by having the notices go out at stated periods. That notice might be as it is with certain groups of societies to-day, a long list on which the meetings of A Society will be held, B Society, C Society, the different groups. The mailing would be done through the central office. In that way you would save a substantial amount of money in the clerical work of getting those notices out and in the cost of printing. Personally I believe that finally the Affiliation may well publish a journal to embody the important papers of the various organizations. That matter is wholly in the air; it has not been broached in the discussions of the men who have been particularly interested in the possibilities of this movement, so that that question will be decided later on by the Council with the approval of the societies affected. If this organization still wished to publish its own independent journal it would go on doing so. The Affiliation cannot of course say that it shall not do so; it cannot force it to support the other measures; but I believe it would be advantageous to the members of this Association if it were possible in the future to have the publications in one volume so that you would have the advantage of the interesting papers which are published by the Mechanicals, the Electricals, by the men of other groups as well as your own. But that is wholly in the air.

I do believe sincerely that this Affiliation will broaden the opportunities for men who are members of this organization. There will be under the plan as contemplated no overlapping dues. If a man is a member of three or four or five different organizations, as a number of the men in this hall are, the dues will be paid but once to the Affiliation. That is

one of the things which must and will be adjusted undoubtedly. Have I answered all your questions?

Mr. Heffernan. Yes.

The President. Any other questions? Mr. Metcalf has made a motion that the New England Water Works Association approves the purpose and principle of the proposed Affiliation and authorizes its Executive Committee to determine, after careful investigation, whether or not this Association shall join said Affiliation, and if the decision shall be favorable, to appoint two representatives of this Association with power to act for this Association upon the Council or other representative body of the Affiliation. Is the motion seconded?

[The motion was seconded.]

Mr. Henry V. Macksey. In the circular sent out with regard to the Affiliation, there was a statement that the assessment on the various associations entering would not be more than $3 per year per member. Three dollars per year per member is not a large amount of money and we know that we do get some benefit from our present connection with the Boston Society of Civil Engineers and that we have had that benefit for years. We have not paid a great price for it and we ought to be willing to help them if their financial load is becoming too heavy to bear. It seems to me that we should consider whether, if we are called upon to pay $3 per year to the Affiliation, we would have enough remaining to carry on our own work and our own activities without materially increasing our dues. Many of us are paying dues to a number of societies and the total is a considerable sum. Would it not be well for us to consider the financial side more closely before our committee binds us by this agreement? We can very easily go in and while it may be easy to drop out again it could not be done gracefully. If we go in we must stick and carry through. What are we to gain at present other than that we will be in touch with other societies when we desire to take part in a public movement and that we will have a little more privilege in the apartments that we now occupy? The financial side should be presented more definitely, because, as Mr. Metcalf has said, it will not reduce our running expenses; in fact, will increase them. We cannot increase our running expenses without increasing our dues. There are many of us who believe that our own Journal dealing only with water works matter is fully as useful if not more useful than one in which the best of our papers are incorporated with papers that are interesting to mechanical engineers, electrical engineers, gas engineers and others with whom we have no close business or professional connection and whose papers would be of no interest and perhaps go over the heads of many of our members.

The President. I am glad Mr. Macksey has raised this question, because I think it is one that ought to be considered by the members before they vote on this proposition. While a definite statement cannot now be presented as to the cost to this Association of entering the Affilia-

tion, I can perhaps make an approximate statement which will leave the members content to give the Executive Committee power to act in this matter.

The assessment payable to the Affiliated Technical Societies will cover the cost of rent, of clerical services at headquarters, of printing and mailing notices, and of such other items which now altogether cost — under our present arrangement — somewhat under $3.00 per member. The prospectus of the proposed Affiliation states that the assessment shall not exceed $3.00 per member and — assuming this to be the figure finally adopted and that for this assessment we shall be housed and furnished services by the Affiliation, which now cost us but little less than $3.00 per member, it follows that the final cost to us will be about the same as at present, and it is, therefore, from present information not anticipated that any increase in dues will be necessary.

I assume that the Executive Committee — if authorized to act for the Association in this question — will carefully analyze the expense involved before deciding to enter the Affiliation, and knowing, of course, that the dues cannot be increased without vote of the Association and an amendment of the Constitution, will make their arrangements accordingly.

Mr. Patrick Gear. Mr. President, if there is any superintendent here listening to this argument, I don't want him to go out of the hall by and by and say, "Well, it is too bad that we affiliate and become a small toad in a big puddle instead of being a big toad in a small puddle, as we are now." I am in favor of the Affiliation, but I don't want any superintendent to come around to me by and by and say, "Well, why did you allow that to go through in the Executive Committee?" I am in favor of it; I think it is a good thing. If we are affiliated with those men it will be a big help to us. We can make lots of acquaintances. I can go home and say, "I met a lot of big fellows in Boston; I was talking to them." [Laughter] If anybody has any fault to find, now is the time to find it.

Mr. Metcalf. May I say just one word? I am in sympathy with Mr. Macksey's viewpoint in regard to facing the question of finance. It is a perfectly proper question. The approximate rough analysis which I made of the expenses indicated that probably the increase in dues at the present time would be likely to be less than fifty cents, or somewhere about that figure. And as I said before, ultimately, and perhaps immediately, there would be a decrease. It was for that reason that I stated that it did not seem to me that it was likely to make any material difference to anybody in this organization in a financial way. So far as the publication is concerned, that, as I stated before, is a matter for the future. It is not involved in the present discussion. We have that and will still have that in our own hands.

The President. Those in favor of this motion will please say Aye. [General response.] Opposed, No. [No response.] The motion is unanimously carried. [*Adjourned.*]

SAMUEL EVERETT TINKHAM.

Samuel Everett Tinkham, who died on April 21, 1921, was born in Taunton, Massachusetts, on March 31, 1852. After attending the public schools and receiving additional instruction by a private tutor, he entered the newly established Massachusetts Institute of Technology, from which he was graduated in 1873 with the degree of Bachelor of Science in Civil Engineering. This was the sixth class to be graduated from this institution and he was, therefore, one of its earliest graduates.

After graduation, he served for a year as assistant in the Corps of Engineers of the United States Army, being employed on harbor improvement work in Edgartown, Massachusetts. In October 1874, he entered the engineering service of the City of Boston, with which he was continuously connected up to the time of his death except from 1882 to 1884 when he served as assistant engineer on the New York and New England Railroad in charge of the design and construction of bridges for the double tracking of that road. His services for the city prior to 1882 consisted chiefly of bridge engineering, although his duties also included work on the Boston Main Drainage System particularly in connection with the design and construction of the Calf Pasture Pumping Station of that system.

Soon after his return to the employ of the city in 1884, he received the title of Assistant Engineer and Principal Draftsman of the Engineering Department and until the late 90's his work was largely that of office supervision of the preparation of plans for highway bridges, a considerable number of such bridges being designed and constructed during this period under the direction of the Boston Engineering Department. As the engineering activities of the city increased, they became in time so extensive as to require him to devote practically all of his attention to supervision of construction, leaving the preparation of designs to others, and during the last quarter century of his service, he supervised the construction of many engineering projects of large magnitude, including not only bridges but grade crossing eliminations, sea walls and difficult foundations.

In the reorganization of the city departments which took place in 1911 and resulted in the establishment of the present Public Works Department, Mr. Tinkham was made Construction Engineer of the Bridge and Ferry Division, a position he continued to hold until his death. He also served as Acting Division Engineer in 1914 and 1915.

In addition to his engineering work for the city, Mr. Tinkham served as consultant on many bridges built in various parts of New England, on buildings and on foundation problems as well as upon certain phases of construction of the Metropolitan Waterworks System.

While his active engineering work brought him into close contact with City, State and Public Service engineers in the Boston Metropolitan district,

he was better known to the engineering profession at large, particularly in New England, as the genial, efficient and alert secretary of the Boston Society of Civil Engineers, a position which he filled with marked ability for 27 years preceding his death. During this long period, the interests of the Society were always prominent in his mind. New presidents took office knowing that in Mr. Tinkham they would find not only a thorough knowledge of the affairs of the Society and of the problems that confronted it, but that they would also receive his hearty and effectual coöperation in any measure that had to do with its welfare. Members at large knew that they would receive from him a cordial greeting at Society meetings and sincere and effective assistance in making use of the Society organization. His re-election year by year by general vote of the Society was a foregone conclusion.

In addition to his services for the Boston Society of Civil Engineers, he was for many years a member of the New England Water Works Association and was also active in the affairs of the American Society of Civil Engineers, having twice been a member and once chairman of its Nominating Committee and having served also as a member of other committees.

Amongst other of his numerous activities may be mentioned his connection with the Civil Service Commission of Massachusetts. In 1897, the provisions of the Massachusetts Civil Service law were extended to include engineers in municipal employ and in 1902 to include also engineers in the employ of the Commonwealth of Massachusetts. Mr. Tinkham was appointed, in 1897, as one of the members of the first Board of Examiners for civil engineers in the Classified Service, which position he held for more than fifteen years. During this time his influence was exerted in placing the examinations for engineers upon a practicable working basis to the end that a man's fitness for appointment to the various engineering positions in the city or state should not be based entirely upon his ability to pass written examinations but also upon experience and demonstrated ability.

This paper would not be complete without mentioning Mr. Tinkham's Masonic activities. As evidence of his faithful service and of the esteem in which he was held by his associates in the Masonic organizations to which he belonged, it is only necessary to cite his services as Worshipful Master of Washington Lodge in Roxbury, as Eminent Commander of Joseph Warren Commandery of the Knights Templars and as President of the Association which controls the Masonic Temple in Roxbury, Massachusetts.

All who knew Mr. Tinkham have a feeling of great personal loss and a sudden realization of how much his unselfish, honest, untiring interest in the various activities, whose success was so close to his heart, is going to be missed.

FREDERIC H. FAY.
F. A. MCINNES.
Committee

HERBERT L. HAPGOOD.

HERBERT L. HAPGOOD was born in Athol, Massachusetts, February 5, 1850. He was the son of Lyman W. and Eliza Hapgood. He was killed by an automobile when crossing the street near his home on the evening of October 8, 1921.

Mr. Hapgood was educated in the local schools and the New Salem Academy, which at that time had a high rating. After graduating from the academy he apprenticed himself in the Baxter D. Whitney shops of Winchendon, Massachusetts. Here the young man's mechanical inventive ability was developed.

Upon his return home in 1874 he entered his father's business, The Diamond Match Company, and carried it on until 1892. He perfected many patents valuable in the production of matches, a sandpapering machine being the most notable.

Mr. Hapgood came of a long line of patriots, municipal leaders all. After retiring from active business he entered enthusiastically into the executive business of the Town, holding the principal office for fourteen consecutive years, together with the management of various other departments, instituting some and supervising the construction of others, the sewage system, for instance. In 1909 Mr. Hapgood was made Superintendent of the Water Department and continued to be chairman of the board of commissioners, which position he had held for several years. He was particularly adapted to this work and it was agreeable to him. He developed the plant to its present efficient system and was formulating extensive improvements at the time of his death. The sand filter which he constructed, has filtered itself into exemplary fame among Engineers.

Mr. Hapgood was by position, disposition and knowledge a veritable Town Father; naturally a student, he weighed all questions imposed upon him from every angle, beginning with the legal and never forgetting the human element. Mr. Hapgood collected and prepared much historical data that is invaluable to the Town and the District — his works are his monument, they will endure without end.

Mr. Hapgood married Mary Josephine Proctor, in 1875; he is survived by his wife and two sons, Lyman P. Hapgood and Frederic H. Hapgood both Civil Engineers, and one daughter, Edith E. Hapgood.

ALFRED EARL MARTIN.

Born September 23, 1852, at Brooklyn, Conn.
Died February 21, 1922, at Springfield, Mass.

In the death of Alfred E. Martin the New England Water Works Association loses a member of sterling worth long active in the work of the Association. He was elected a member of the Association April 21, 1885, less than three years after its organization, and has rendered valuable service on committees from time to time, being honored by election as its president in 1908.

His early education was received in the public schools of his native town and in Woodstock Academy, living in Connecticut until he was twenty-one years of age, and teaching in some of its district schools.

Health prevented the realizing of his ambition for an advanced scientific training, but he continued along technical lines, working as a civil engineer with J. Herbert Shedd, chief engineer of the Providence Water Works and Sewer department, and Howard R. Carson from 1874 to 1877.

He was assistant engineer in charge of the Brookline main sewer, and in construction of a large filter basin in Lonsdale, Rhode Island; was engaged in sewer construction for the City of Boston, and in other construction work.

For four years he was superintendent of the construction work on "Dam No. 4" of the Boston Water Works at Ashland, under the immediate supervision of Mr. A. Fteley, C.E.

In 1885 he became superintendent of the Framingham Water Company, where for eighteen years he was a vital factor in the development of the Framingham system.

On March 1, 1093 he became superintendent of the Municipal Water Works of Springfield, Mass., where during the nineteen years of his service he saw the Springfield system rebuilt along modern lines and more than doubled in size and service.

During his thirty-seven years of service as a water works superintendent he was known as an excellent official and a capable, faithful and conscientious public servant. He was a faithful attendant at the Association meetings and his remarks and counsel were always considered sound and carried weight of practical experience. His frank personality attracted lasting friendships, and, as the Assistant Secretary has so aptly stated, "He will be missed greatly by the older members of the Association, and his genial manner, which was so genuine, will be a pleasant remembrance of him."

In 1879 he married Miss Eleanor M. Flagg of Providence, who died in Springfield, March 8, 1917. Besides a brother, Frank L. Martin of Brooklyn, Conn., he leaves a sister-in-law, Mrs. Clara A. Kilburn, who has lived

with him since Mrs. Martin's death, and four nieces; Miss Celia May Chase, formerly of Newton, Mass., Mrs. Andrew Sharp of Elliot, Conn., Mrs. Abbie Holbrook of Pomfret, Conn., and Mrs. William Farmer of Greenfield, Mass.

Mr. Martin was a past master of Alpha, A.F. and A.M. of Framingham, a member of Springfield Commandery Knights Templar, Massachusetts Consistory 32, and Melha Temple, A.A.O.N.M.S., and was also a past noble grand of the Odd Fellows in Ashland and a member of the Orpheus Club of Springfield and prominent in musical circles in both Framingham and Springfield.

He was one of the first presidents and a founder of the Public Service Associates of Springfield, Mass., a unique local "get-together" organization of officials connected with public work and public utilities in that city, which he helped to form some ten years ago.

Alfred R. Hathaway,
Elbert E. Lochridge,
Committee.

Springfield, Mass.,
April 26, 1922.

New England Water Works Association

ORGANIZED 1882.

Vol. XXXVI. September, 1922. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

THE NEW WATER SUPPLY OF THE CITY OF PROVIDENCE.

BY FRANK E. WINSOR.*

Present Supply and New Supply Compared. The present supply is taken from the Pawtuxet River at Pettaconset with a drainage area of 199.6 sq. mi. where the water is first pumped from the river to filter beds, is filtered and again pumped to a distributing reservoir about 170 ft. above the filters, from which is supplied the low service area of the city.

For some years the quantity used has been considerably greater than the natural low flow of the river and the supply has been maintained by water stored by the mills located above the intake and let down by them for their own use.

The water at the present source is polluted by trade wastes and human dejecta, most of which enters the river from mills and mill villages having an aggregate population of over 30 000 people and located within a radius of about 8 mi. of the pumping station.

The new supply will be taken from about 92.8 sq. mi. of drainage area which is a part of the area tributary to the present supply but which is above practically all sources of pollution. It involves the building of a large storage reservoir on the north branch of the river from which water will be conveyed by gravity to an elevation about 50 ft. higher than the present distributing reservoirs which serve the low service area of the city. The drainage area of the new reservoir, while slightly less than half that tributary to the present pumping station, will be sufficient with available storage to guarantee a safe yield to the city of 85 m.g.d. or nearly four times the present consumption and fully seven times the natural low water flow at Pettaconset.

Details of Present Supply. Agitation for a comprehensive water supply for the City of Providence began about 75 years ago. In March, 1853, the City Council created a committee of investigation and between this date and 1868 five different committees made six separate reports. The water supply project was three times defeated by votes of the tax payers, who, however, finally approved the plan which provided the present supply.

*Chief Engineer Providence Water Supply Board.

the first service pipe of which was opened on December 1, 1871. The present supply is under the able direction of City Engineer, Milton H. Bronsdon, member of this Association.

Water is taken from the Pawtuxet River at Pettaconset, about $3\frac{1}{2}$ mi. from tide water and at about elevation 10.* Since 1905, when filtration was introduced, water has been first pumped from the river by low lift pumps to the filters from which it flows to an open pump well and is again pumped to Sockanosset Reservoir about a mile distant at an elevation of 181.75.

Sockanosset Reservoir is about $5\frac{1}{2}$ mi. from the center of the city and from it is supplied by gravity most of the area of the water district below elevation 90. The water from this reservoir also flows into Hope Reservoir located near the center of the city at elevation 162.5, which latter reservoir serves to equalize fluctuations of consumption and provides a considerable storage near the center of population. There is another pumping station at Hope Reservoir which raises water to the high service storage reservoir at Fruit Hill at elevation 274.75, from which those parts of the city above about elevation 90 are supplied, and which also furnishes high pressure to a special fire district covering generally the congested business area of the city. About 15 per cent. of the present consumption is used in the high service area. The filter plant, prior to the completion of which, in 1905, water was used direct from the river, consists of 10 acres of slow sand beds, originally open but after a short period of operation roofed over with concrete groined arches covered with earth. The filters are generally operated at a rate somewhat less than 3 million gallons per acre daily. For the past 5 years the safety of the water has been further assured by chlorination subsequent to filtration.

Pumping Equipment in General Use.

At Filter Plant Lift about 9 Feet. 2 DeLaval horizontal centrifugal pumps direct connected to Bullock 500-volt D.C. 50 h.p. motors, current for which is either generated by steam at the Pettaconset Pumping Station or is purchased from the Narragansett Electric Lighting Co. Capacity of each unit 20 m.g.d.

At Pettaconset Station Lift about 172 Feet. 1 Allis-Chalmers vertical triple expansion engine and pump, capacity 25 m.g.d. 1 DeLaval horizontal centrifugal pump direct connected to a General Electric 2 200-volt A.C. 1 300 h.p. motor, current purchased from the Narragansett Electric Lighting Co., capacity 30 m.g.d. There are three other pumps located at Pettaconset, some of which are obsolescent, which have a combined rated capacity of about 29 m.g.d.

All of the above pumping plant will be abandoned following the introduction of the new supply.

*Elevations are above mean high water of Providence harbor.

At Hope Reservoir Lift about 112 Feet. (High Service.) 1 Worthington horizontal triple expansion engine and pump, capacity 10 m.g.d.

1 DeLaval steam turbine driven centrifugal pump, capacity 8 m.g.d.

About one half the present high service area may be supplied by gravity from the new system and the future lift will be greatly reduced.

Reservoirs.	Elevation (full).	Area Acres.	Capacity Million Gal.
Sockanosset	181.75	11.0	55.0
Hope	162.50	12.5	76.0
Fruit Hill	274.75	4.5	25.0

It is probable, owing to the future higher level of gravity distribution that Sockanosset and Hope Reservoirs will be eventually superseded by a new covered reservoir on Neutaconkanut Hill at the west side of the city at an elevation of about 225. Fruit Hill reservoir will also probably be eventually superseded by a new covered high service reservoir about ½ mi. northerly from it at an elevation of about 305. Land for both of these new reservoirs has already been acquired by the city. Inasmuch as the new supply will eliminate all pumping, except to a much reduced high service area, thus reducing the hazard of interruption of service, the tentative designs of the new covered distribution reservoir contemplates much less storage capacity than at present, with, however, provisions for enlargement as the consumption increases.

The sizes and lengths of pipe in the present system are as follows (as of December 31, 1921):

42 in.	25 631 ft.
36 in.	10 242 ft.
30 in.	61 592 ft.
24 in.	50 824 ft.
20 in.	9 626 ft.
16 in.	115 659 ft.
12 in.	184 800 ft.
10 in.	14 622 ft.
8 in.	351 816 ft.
6 in.	1 515 815 ft.
	2 340 627 ft.

Number of public fire hydrants in use December 31, 1921,	2 702
Number of services in use December 31, 1921	34 055
Number of meters in use December 31, 1921	32 232
Per cent. of services metered December 31, 1921	95

The area supplied includes portions of City of Cranston and of the Towns of North Providence, Johnston and Warwick.

Statistics of population, estimated consumption, etc., are shown upon the diagram below, Plate 1.

The population, and per capita consumption calculated therefrom, shown on Plate 1 by full lines, are based from 1915 to 1920 inclusive upon

the assumption that the change in population from the State Census in 1915 to the Federal Census in 1920 was proportional to the time. It is the writer's belief that the Federal Census for 1920 was much too low.

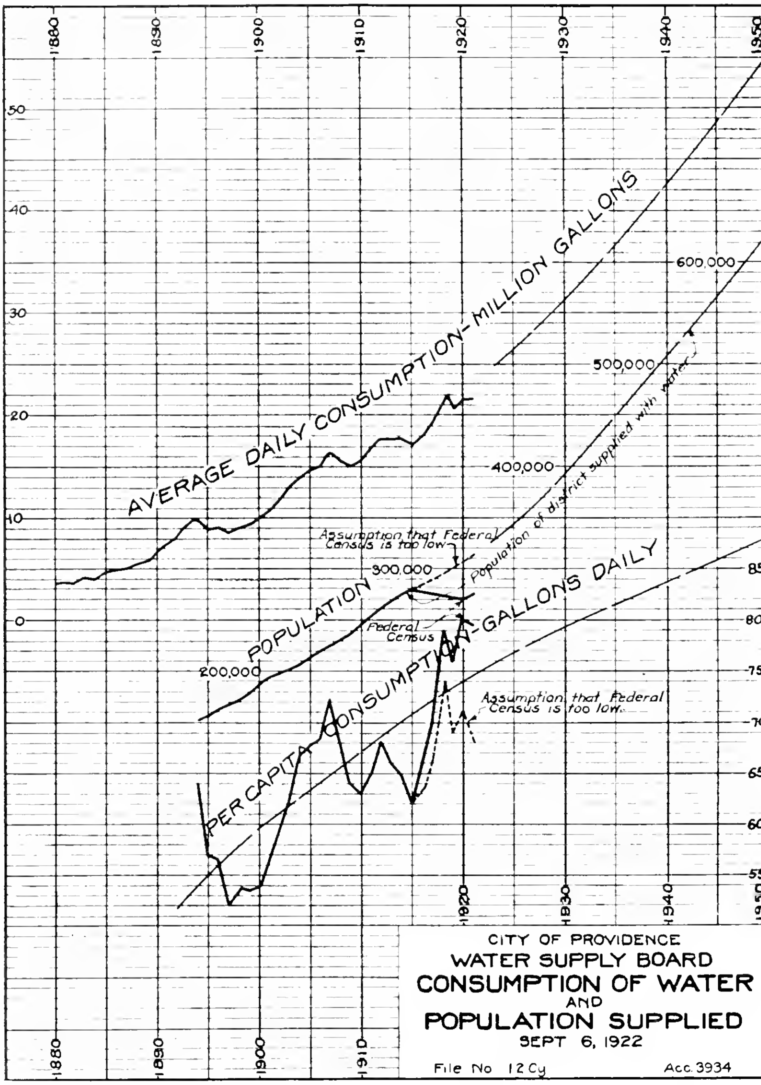


PLATE I.

If the City Engineer's estimate (as published in his Annual Reports) of population of water district from 1916 to 1919 be used, and the writer's estimate of 305 000 for 1920 and 312 000 for 1921 be taken, the population and per capita consumption for each year are shown on this plate by broken

lines. Estimated future population is based upon past growth and the increase which has actually occurred in cities similar to but now larger than Providence. Future per capita consumption is believed to be conservatively estimated and assumes a metered system coupled with the same careful management which has characterized the water works from their beginning.

The average hardness and alkalinity of the river water of the present supply in parts per million was 10.5 and 6.4 respectively for 1921.

In 1921 the average color of the present supply before and after filtration was 45 and 29 respectively. The filters remove nearly uniformly about one-third of the color in the raw water. The filtered water varies in color from about 15 to 50 with occasional higher peaks, for example, in the summer of 1916 it was above 60 for about three weeks and in August, 1922, a maximum of 54 was reached. Even when most highly colored the water is bright and sparkling, the color being a vegetable stain or dye.

The gross revenue of the water works has increased from about $855 000 in 1913 to $986 000 in 1921. The outstanding bonded indebtedness on December 31, 1921, was $1 632 000 old bonds and $1 600 000 for new works. It is expected that with some slight readjustment of water rates, the net income from the water works will be sufficient to defray interest and sinking fund charges on the new water supply, and additions to and changes in the distribution system, all of which are now estimated to cost about $20 000 000.

Details of New Supply. Investigations for a new supply were begun by a committee of the City Council in 1913. An Act was presented to the General Assembly of the State at the January session, 1914, but failed to pass, and after some modification the present Act, under which the work is being carried on, was passed at the following session and became a law on April 21, 1915.

Some rather unusual features of the law are as follows: —

(a) As one of the results of the preliminary investigations and discussion the outside boundary within which the City could condemn land for reservoir purposes was prescribed.

(b) The right of condemnation of either land or water rights was limited to two years after passage of Act.

(c) In case a part only of any farm or of any lot or tract of land is taken under any of the provisions of this Act . . . . . and the remainder or any portion thereof . . . . . is damaged or lessened in value by such taking, the owner or owners thereof may surrender to said City the portion so damaged or lessened in value . . . . within one year after said taking; whereupon, the portion so surrendered shall be deemed to be included in such taking . . . . . (applies to taking for reservoir only).

(d) Similar provision for surrender of mill property including reservoirs, dams, etc.

(e) Owners of land contiguous to that taken for reservoir purposes, which is directly or indirectly decreased in value thereby, are permitted

to recover, provided they filed a claim within three years after passage of Act.

(f) Damages to business and damages for loss of employment are provided for.

(g) Very elaborate provisions are made for the regulation of flow in the stream past the dam from the time the city first begins to interfere with the stream; e.g., the city cannot hold or divert any water until the reservoir is ready for use; from the time the city first begins to store water until for the first time 20 000 000 000 gal. have been stored, the city shall not reduce the natural flow of the stream during any week day, except that it may hold any water in excess of 20 m. g. d. flow; after 20 000 000 000 gal. are first stored the city shall draw from the reservoir not less than 70 m.g.d. and the portion of this not used for water supply shall be discharged into the river below the dam, concentrated so as to best meet the requirements of the mills below (the above quantity of 70 000 000 gal. may be temporarily reduced to 65 000 000 gal. provided the reservoir does not fill by June 1 in any year); the city shall forever discharge 500 000 gal. per day from the reservoir and such further amount as may be necessary to maintain a flow of 6 000 000 gal. each day into the Arkwright mill pond (located about 3 mi. downstream from the reservoir with an intermediate drainage area of 9.4 sq. mi.); also under certain conditions such further amount as may be necessary to maintain a flow not exceeding 72 000 000 gal. weekly into the Clyde mill pond (located about 5 mi. downstream from the reservoir with an intermediate drainage area of 13.2 sq. mi.); the city is required to establish and maintain gaging stations at or near Arkwright and Clyde.

The Act at its passage in April, 1915, established an unpaid Water Supply Board consisting of the seven persons who then constituted the committee on increased water supply previously appointed by the City Council. The personnel of the Board has remained unchanged and their sustained intelligent interest and unselfish public service has insured a continuity of policy which has been a potent factor in the prosecution of the work. The preliminary investigations prior to 1915 were made under the direction of the late Samuel M. Gray, then a member of this Association, and the general plans then outlined have been followed in the subsequent development of the project. The writer became Chief Engineer in August, 1915, and complete topographic and real estate surveys were pushed to completion as rapidly as possible. Horizontal control was insured by a rectangular coördinate system established by triangulation and vertical control by a net of precise levels. Subsurface investigations for all structures were begun almost immediately. All structures connected with the reservoir, including relocated roads, new cemetery, dam, dike, etc., were located, approval obtained from various authorities as necessary and title taken by condemnation to the entire area of 12 450 acres on December 6, 1916. Similarly title was taken to land required for the aqueduct on April 4, 1917.

The first construction contract, for river control at the Main Dam, was let in January, 1917, and it was then expected to follow this with a contract for the major part of the work on the dam in the fall of that year.

Owing to the coming on of war in April, 1917, the major contract referred to was not let until May, 1921, and the completion of the entire work has been of necessity delayed thereby from two to three years. It is now expected to begin storage of water in the summer or fall of 1925 and, dependent upon rainfall and run-off, to begin furnishing water either in the summer of 1926 or the following winter. The essential construction program should be completed in 1926 if present plans are carried out.

Following is a summary of statistics of the new supply:

Scituate Reservoir

Drainage area	92.8 sq. mi.
Storage capacity	36 900 000 000 gal.
Area of water surface	3 600 acres.
Average depth of water	32 ft.
Flow line elevation above mean high water of Providence harbor	284 ft.
Maximum depth of water (in river bed at dam)	87 ft.
Length of east branch, measured from dam, about	7 mi.
Length of west branch, measured from dam, about	5.7 mi.
Maximum width, near dam, about	2½ mi.
Length of flow line, not including islands, about	38 mi.
Number of islands	28
Highways to be abandoned (including 7.4 mi. regraded)	34.7 mi.
Highways to be built and regraded	26.0 mi.

Real Estate.

Area which City was permitted by law to acquire	16 000 acres
Area which City condemned for reservoir	12 450 acres
Length of main taking line	56 mi.
Total area which City condemned for reservoir, new highways and cemeteries	12 547 acres or 19.6 sq. mi.
Total area, including property surrendered, which City will control, about	15 000 acres
(Total area of the City of Providence is 11 700 acres)	
Dwelling houses on condemned area	357
School houses on condemned area	7
Churches on condemned area	6
Cotton mill plants on condemned area	6
Total buildings on condemned area	1 195
Cemetery lots on condemned area	173

Main Dam.

Length, about	3 200 ft.
Maximum height above valley, about	100 ft.
Maximum height above bed rock, about	180 ft.
Maximum thickness at base	640 ft.
Thickness at flow line	118 ft.
Width on top, 13 ft. above flow line	37 ft.
Cubic contents of dam, including refilling below surface of the ground, about	2 500 000 cu. yds.
Length of spillway at west end of dam, (net) about	413 ft.
Length of spillway channel to river below dam, about	1 800 ft.

Dike.

Length, about	4 000 ft.
Maximum height above the surface of the ground, about	33 ft.
Average height above surface of the ground, about	15 ft.

Aqueduct.

Total length from gate house in dam to present distribution system, about	7 mi.
Land condemned, about	80 acres
Minimum width of taking	50 ft.
Maximum width of taking (except at shaft and tunnel portals)	200 ft.
Tunnel, concrete lined, equivalent to about 7 ft. 9 in. diameter circle	$3\frac{1}{3}$ mi.
Depth of construction shaft, about 7 200 ft. from east portal	140 ft.
Masonry aqueduct or pipe lines in open cut	
West of tunnel	1 mi.
East of tunnel	$2\frac{2}{3}$ mi.

Scituate Reservoir. After a thorough investigation it was decided in 1916 not to strip the top soil from the area to be flooded as was done at the Wachusett Reservoir of the Metropolitan System, as the benefits therefrom would, it was believed, be incommensurate with the cost. It is the writer's opinion that, while removal of soil may be and in some instances undoubtedly has been very beneficial in the early years of a reservoir's use, it probably accomplishes little or nothing of permanent value and that it cannot be considered in any sense a satisfactory substitute for filtration. With present and prospective wage scales and the proportion of hand labor involved, it seems reasonably certain that soil removal from large storage reservoirs will seldom if ever be economically justified in the future. The reservoir area including a 30-foot marginal strip will be cleared of all vegetation immediately prior to flooding and stumps and roots will be generally removed from areas to be submerged less than about 25 ft. It was also decided in 1916 to filter the new supply.

The principal shallow flowage area is at the upper end of the east arm of the reservoir and to insure keeping this area flooded when the main reservoir is drawn down, and to provide, before the completion of the new project, some storage which could be sent down the river, if and as needed, to the present Pettaconset Pumping Station, a structure known as the Regulating Dam was designed and built in 1918 at the village of North Scituate. The dam floods an area of about 210 acres to a maximum depth of about 12 ft., with an average depth of about 5 ft. at Elevation 284, the level of Scituate Reservoir. In order to increase the capacity temporarily the reservoir has been maintained generally at Elevation 285.5 by 18-in. flashboards, thus providing a storage of about 420 000 000 gal. which has been available if and as needed at Pettaconset since the spring of 1919. This dam as shown on the accompanying photograph is circular in plan and of a true arch type. The radius of the upstream edge of the dam is 50 ft. and the ends near the highway connect with the abutments of the

REGULATING DAM AT NORTH SCITUATE.

With 7 inches depth of water over flashboards, September 12, 1919.

(Since the photograph was taken the ends of the dam have been extended to the nearer cross walls and additional walls added to connect with the wing walls of a new bridge just downstream.)

new Danielson Pike Bridge by reverse curves. The spillway has a net length of about 220 ft., the concrete crest being at the same elevation as the crest of the spillway of the Scituate Reservoir about 6 mi. below. The dam is mainly on coarse sand and gravel and water-tightness was secured by placing a blanket of soil and subsoil 2 ft. thick, rolled in thin layers, outside the wall of the dam for a radial distance of 75 ft. The concrete section except at the abutments and gate chamber, is L shaped being 15 ft. high and vertical on the water face and 10 ft. wide on the bottom. The thickness of the wall at the spillway level is 30 in., and 12 ft. down, 42 in., this being the level of the concrete apron which forms the horizontal part of the L and which is 3 ft. thick. The water falls over the spillway and drops 12 ft. on to the concrete apron, which is 6 ft. 6 in. in width. The bottom is further protected by paving 6 ft. in width and additional protection is provided in front of the gate chamber through which the water is drawn off.

Scituate Aqueduct. The Scituate Aqueduct runs in an easterly direction from the Main Dam to the present distribution system near Sockanosset Reservoir and is about 7 mi. long, $3\frac{1}{3}$ mi. of which is in tunnel, a contract for which was awarded September 6, 1922. The westerly end of the aqueduct at the Scituate Dam is only about 10 mi. from the civic center of Providence and when the great distances that many cities have had to go for water are considered, it is remarkable that a sparsely settled drainage area of 92.8 sq. mi., all situated in the small state of Rhode Island, is available so near at hand.

Subsurface Investigations. Subsurface investigations were begun late in 1915. These investigations may be divided into 4 classes:

1. Wash borings to the surface of the rock, followed by diamond drill borings into rock.
2. Wash borings to determine character of material except rock.
3. Rod soundings to eliminate rock to the depth of the sounding.
4. Test pits.

(1) Work under class 1 was done entirely by contract with Sprague & Henwood, Inc., of Scranton, Pa. The material overlying the rock contains commonly boulders of both large and small size and core borings only were depended upon for accurate information as to the locations of ledge rock. In connection with the investigations for the dam, tunnel and other works, a total of 202 borings was made in this class aggregating 5 202 ft. of wash boring and 3 738 ft. of core boring in rock. The total cost of the work, exclusive of administration and engineering, was \$18 416, making the average price paid per foot for wash and core borings respectively, \$1.65 and \$2.63. Great care was taken in the preservation of cores in rock and to obtain accurate information in regard to the character of the overlying material. Some of the provisions of the specifications are as follows:

An accurate record shall be kept of all materials penetrated as well as the depth of each boring. Samples of the materials penetrated, other than cores of rock, shall be taken in the manner, and as frequently as directed, placed in receptacles, furnished by the Board, which shall be so numbered and marked as to be readily identified, and shall be delivered in boxes, furnished by the Contractor at such places as the Engineer may direct. The cores of rock shall be carefully handled so that they will not be destroyed or injured. They shall be carefully preserved, marked and placed in wooden boxes, furnished by the Contractor, of a design approved by the Engineer. Upon the completion of a hole the covers of the boxes shall be securely screwed on and the boxes delivered at such places as directed and shall remain the property of the City. Should it prove impracticable at any depth to obtain a core, or should a seam be encountered, particular care shall be taken to get accurate samples of the materials penetrated and the correct limits between which no core can be obtained.

It is important that as large a percentage as possible of the cores shall be recovered, and the Contractor shall regulate the speed of his drill and remove the core as frequently as directed in order to maintain a maximum percentage of recovery, special care being taken where the character of rock being penetrated is uncertain. If the appliances on any machine are not such as will give a reasonable amount of core in the opinion of the Engineer, the Contractor shall furnish such appliances as will be satisfactory.

Blasting with small charges will be allowed for the removal of a boulder or other obstruction which cannot be conveniently removed otherwise.

The Contractor shall drive to such depths as directed, generally to sound bed-rock, a wrought-iron or steel casing at such points as are designated These casings shall be of such sizes that it will be feasible to continue the boring into bed-rock, as a core boring.

The casings for the wash borings are to be driven by some suitable form of wash-boring rig that will penetrate all material other than sound rock to be found in the territory to be explored and give the speed required for the completion of the work. The wash water may be used repeatedly if necessary, but sufficient tubs or buckets shall be provided to allow all the coarser material to settle out before using the water again. Where the character of the material will permit, it is desirable to drive not over 5 ft. before each washing, and under no circumstances may the wash pipe advance more than 6 in. below the bottom of the casing.

The Contractor shall provide all facilities and assistance necessary to secure samples of materials penetrated whenever required. Dry samples obtained by forcing the sampler tube below the limits of the washing, will, in general, be required about every 5 ft. in depth and may be required at more frequent intervals.

Whenever ordered, wash borings which have been carried to sound bed-rock shall be further continued by core borings into the sound rock to such depths as may be deemed advisable by the Engineer, usually about 20 ft. Unless otherwise permitted, cores shall have diameters of not less than $1\frac{3}{4}$ inches if diamond drills are used and not less than $2\frac{1}{2}$ inches if shot drills are used.

While the specifications permitted using shot drills, the contractor actually used only diamond drills. The method used in obtaining samples was also used in all wash borings done under (2) and was found to be extremely satisfactory, the materials indicated by the samples being thus far in very close agreement with those found where actual excavations have been made.

In addition to the diamond drill borings made by the Board, 27 borings having an aggregate depth of 790 ft. in earth and 358 ft. in rock were made by the Committee of the City Council, mainly in 1914.

(2) Extensive investigations were made by wash borings to determine the character of material available for building the dam, and to obtain negative information as to rock at various other structures. The method of taking samples was the same as already described and no samples were permitted to be taken of material washed out of the various holes, unless it was found impossible to get dry samples. One hundred twenty-two borings having an aggregate depth of 3 046 ft. were made.

(3) Rod soundings made by driving a rod into the ground were also made by employees of the Board, the aggregate depth for 1 264 soundings being 6 649 ft.

(4) 1 143 test pits were made for a variety of purposes, some 725 of them (total depth 1 750 ft.) being to determine the material available for impervious core, which investigation covered a very large area below the flow line of the reservoir.

Nearly all of this work was done by labor directly employed by the Board.

Rainfall and Run-off. A record of the rainfall and run-off on the North Branch of the Pawtuxet River has been kept since 1916, indicating conditions in general similar to those of the Wachusett Reservoir for the same period. The average yearly rainfall for the past six calendar years was 48.8 in., with an average run-off, from land surfaces only, of 57.5 per cent. the corresponding figures for the Wachusett drainage area being 45.1 in. rainfall and 57.8 per cent. run-off from land surfaces only. The estimated average long term rainfall on the Scituate Reservoir drainage area is about 45.5 in. as compared with the Wachusett average from 1897 to 1921 inclusive, of 45.3 in. The average elevation of the drainage area of Scituate and Wachusett Reservoirs are 470 and 750 ft. above sea level respectively. Detailed figures of rainfall and run-off are given in the annual reports of the Water Supply Board and also in *Water Supply Papers 501 and 521* of the U.S. Geological Survey.

Four standard 8 in. Friez rain gages are maintained and a Gurley automatic elevation-recording stream gage makes a continuous record of the depth of water on the Fiskeville dam, an unused mill dam about $3\frac{1}{2}$ mi. downstream from the Scituate Dam, the watershed area of which is 101.8 sq. mi. The discharge curve for the Fiskeville dam was based on experiments at Brown University in 1916 on a model section checked by current meter observations at a convenient point a short distance upstream and further checked by published experimental data in *Water Supply Paper No. 200* of the U. S. Geological Survey and elsewhere. There have been no floods of magnitude since the gaging station was established, but it is of interest to note that the two highest run-offs occurred in July and September of this year, the peaks at Fiskeville being 26 and 28 second feet per

square mile of total drainage area. At the time of the July storm a peak of 50 second feet per square mile was reached from 22 sq. mi. of this same drainage area at the regulating dam at North Scituate. The summer rainfall and run-off of 1922 has probably seldom if ever been exceeded in this locality.

Quality of Water in Scituate Reservoir. The average hardness and alkalinity of the water flowing past the site of the Main Dam during 1921 was about 6.3 and 4.0 parts per million respectively. The color of the present stream at the Main Dam, based mainly upon observations during the past 6 years, averaged 46 with considerable variations. On 48 sampling days in 1916 the average color was 43, 36 of these days being between 26 and 50 and 12 days between 51 and 100. On 31 sampling days in 1917 the average color was 39, 28 of these days being between 26 and 51, and 3 days between 51 and 100. In the early years after filling it is probable that there will be little if any improvement in color over the average of the influent water and in fact temporary seasonal increases in color may be expected. It seems certain, however, that after a few years the reservoir with its storage of 400 000 000 gal. per sq. mi. (the Wachusett Reservoir stores about 600 000 000 gal. per sq. mi.) will have a strong decolorizing or bleaching effect upon the water stored. The average population on the drainage area will in 1925 probably not exceed 25 persons per sq. mi., mostly being on isolated farms with, however, some local concentrations, the largest of which will be in North Scituate about six miles above the reservoir intake at the dam. The city owns more than 20 per cent. of the drainage area, the taking line except at North Scituate being generally at least 500 ft. distant from the flow line and averaging over one quarter mile. The type of filters, which will be located between the dam and the tunnel, has not yet been determined. It has not yet been necessary to design the filters, as their construction need not be begun before late in 1923, and in the meantime advantage may be taken of any advances in the art of treating water of this character.

Cemeteries. Upon the area acquired by the city there were 101 farm cemeteries and a community cemetery near Rockland containing about 75 lots. The total number of known bodies was 2 308 which number has been materially increased by the discovery of unmarked graves as the work of removal progressed. About one half of the farm cemeteries are so far distant from the flow line that their removal is unnecessary, although further burials have been prohibited. A new cemetery known as the New Rockland Cemetery was established upon a sandy knoll about $\frac{5}{8}$ mile distant from the flow line of the Rockland arm of the reservoir and 6 miles distant from the dam. The removal of bodies was begun in September, 1918, and this work was practically finished in July, 1922. The development of the cemetery, including drives, etc., was done by forces in the direct employ of the Board, as was also nearly all the work of removal of bodies thereto, moving and resetting headstones, monuments, etc. The new

cemetery was laid out and the plan filed in the records of the town where located. In consideration of a release to all right, title and interest in the old ground, parties interested are given a deed to a lot sufficient for their needs in the new grounds, and the bodies in which they are interested, together with head stones and monuments, moved thereto. Some of the rules of the new cemetery are as follows:

All work in the old and new cemeteries shall be done only by parties previously approved by the city.

All lots shall be bounded by permanent concrete monuments provided by and set by the city, such monuments to be 5 in. square and 20 in. long.

There shall be no curb stones, iron or stone fences or close hedges permitted.

No foot stones will be permitted and foot stones in existing grounds will not be brought to the new grounds.

Head stones shall be set at least as permanently and satisfactorily as in present grounds.

Field stones without lettered inscriptions marking graves in existing grounds will not be moved to the new grounds.

Suitable records shall be kept showing the position of all unmarked graves in the new cemetery and the locations from which they were removed.

The work of removing cemeteries is practically complete, there having been 1 598 bodies removed, of which 1 448 have been moved to the new cemetery, the remainder having been moved to lots provided by parties interested, in other cemeteries, generally in the State of Rhode Island. The grounds have been maintained to date by the city and the approximate cost of the work, including bodies moved to other cemeteries, has been as follows:

Maintenance $2 800, received for original interments, $500, net cost of maintenance $2 300. Development of new grounds $15 800, moving bodies, head stones, monuments, etc., $17 100. Total $35 200. Cost of land $1 700. Total cost including land $36 900. Cost per body moved from old grounds $23.09. The above costs do not include administration, engineering, or fencing, which may later be necessary.

Main Dam and Dike.

The accompanying plans, Plates II and III, show the main features in the design of these structures.

The cross sections of the valley, the character and depth of the material overlying the rock and the ease and economy of construction of an independent masonry spillway founded on rock clearly indicated an earth dam to be the best and most economical type for the Main Dam. Subsurface investigations of the material overlying the bed rock showed it to be a modified glacial drift varying from very fine sand to coarse gravel with very irregular stratification and freely water bearing. The materials

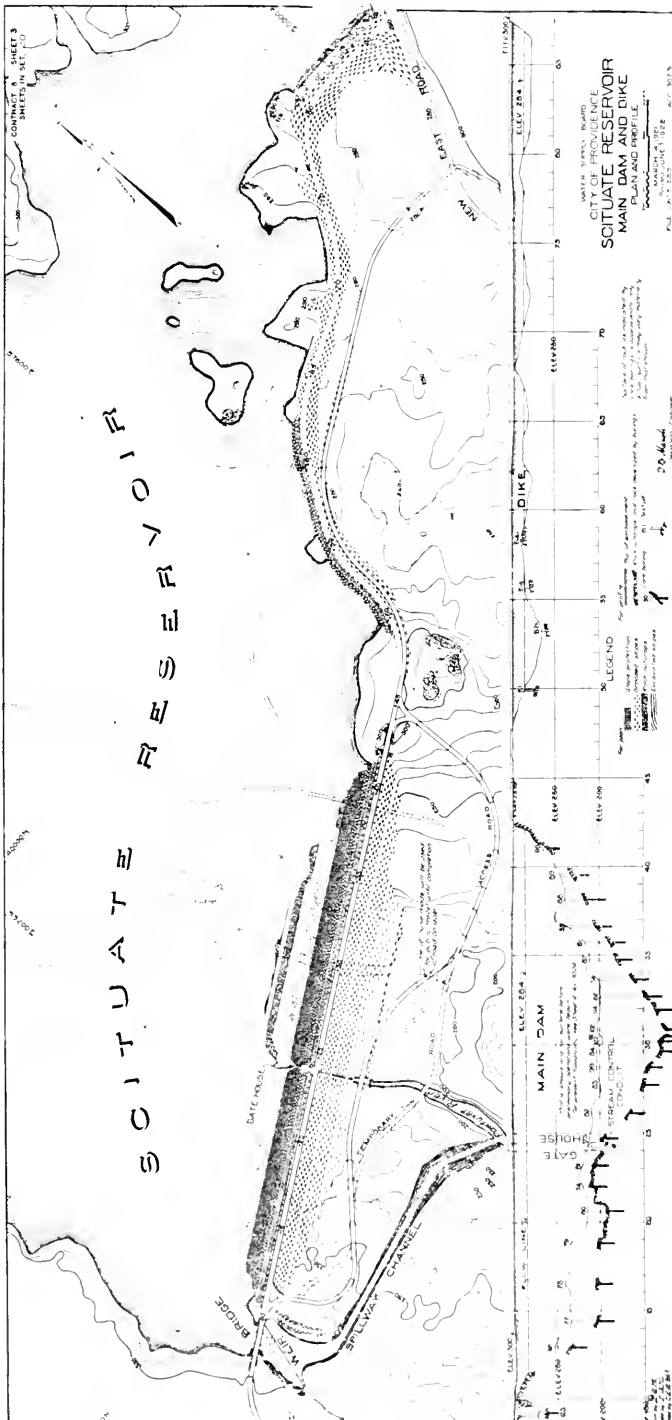

SCITUATE RESERVOIR
WATER SUPPLY BOARD
CITY OF PROVIDENCE
SCITUATE RESERVOIR
MAIN DAM AND DIKE
PLAN AND PROFILE
CONTRACT 8 SHEET 3
MAIN DAM
DIKE
LEGEND
GATE HOUSE
STREAM CONTROL CONDUIT
SPILLWAY CHANNEL
WEIR
BRIDGE
NEW EAST ROAD
ACCESS ROAD
TEMPORARY
FLOW LINE
ELEV 284
ELEV 250
ELEV 200

PLATE II.

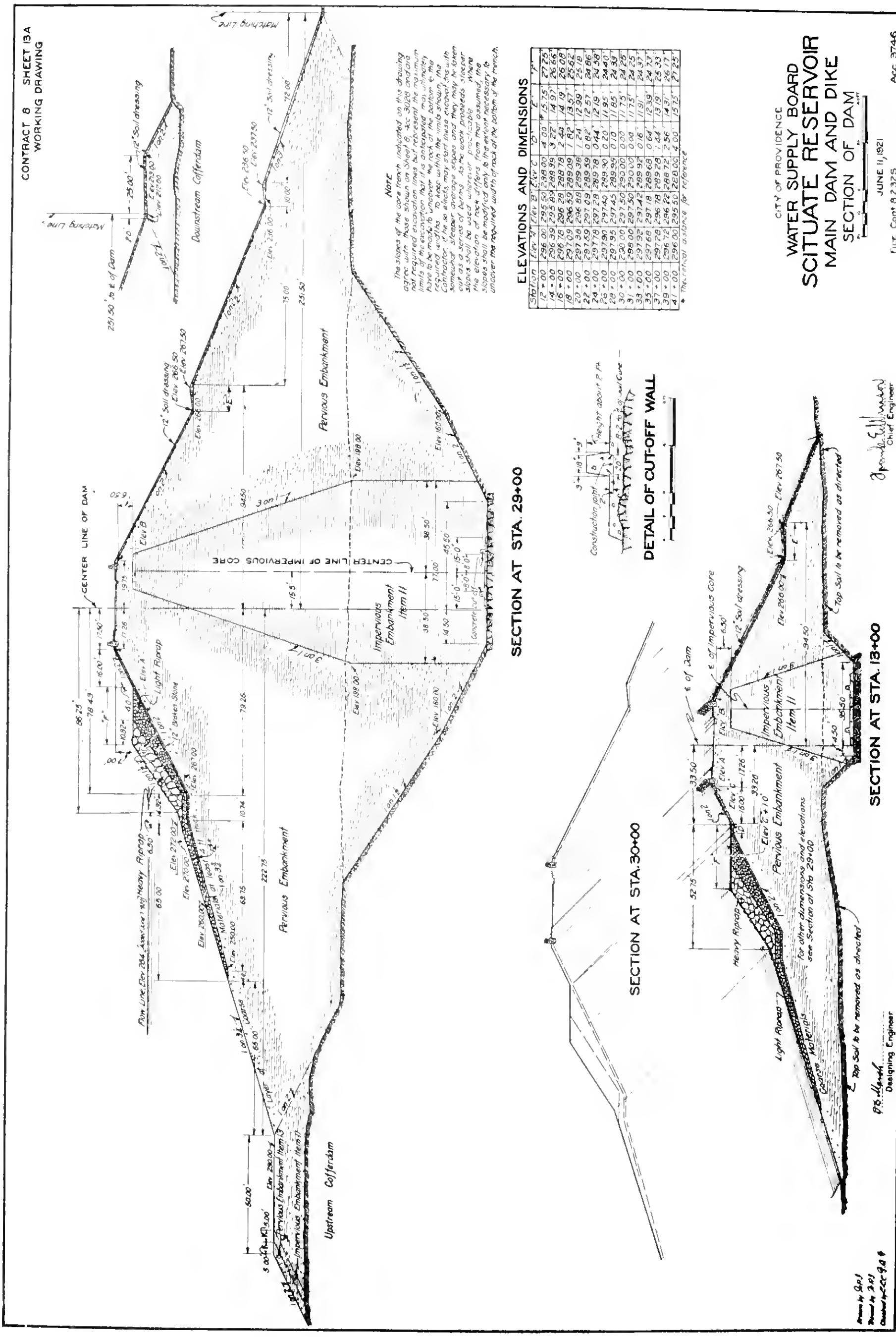

CONTRACT 8 SHEET 13A
WORKING DRAWING
SECTION AT STA. 29+00
SECTION AT STA. 30+00
SECTION AT STA. 13+00
DETAIL OF CUT-OFF WALL
ELEVATIONS AND DIMENSIONS
CITY OF PROVIDENCE
WATER SUPPLY BOARD
SCITUATE RESERVOIR
MAIN DAM AND DIKE
SECTION OF DAM
JUNE 11, 1921

PLATE III.

encountered in the excavations so far made agree very closely with those indicated by the borings. The underlying rock is a granitic gneiss of fairly uniform quality and no fault appeared in the bottom of the rock valley.

The control of the stream during construction was accomplished by diverting it into a horseshoe shaped conduit 25 ft. wide by 21 ft. 4 in. high and 462 ft. long passing through and under the dam, with its bottom elevations substantially the same as the old river bed. This conduit is founded upon ledge rock and is connected with the river by approach and discharge channels about 1 000 ft. and 200 ft. long respectively. The approach channel is lined with concrete up to the height of ordinary river flows, mainly with the idea that the percolation into the deep portions of the core trench during construction might be reduced thereby. The upstream and downstream sides of the deep excavations are guarded by earth embankments forming the toes of the dam and referred to as the upstream and downstream cofferdams. The upstream cofferdam is at a sufficient height to provide without being overtopped, for the continuous passage of about 150 second feet per square mile through the stream control conduit.

Provision for a flood of this unusual magnitude was considered necessary because of the important mill properties on the stream below the dam which might suffer great damage if accumulated storage was suddenly released by the failure of an inadequate temporary structure. It was also very important to avoid any possibility of flooding the deep portion of the cut-off trench during its excavation and refilling. The largest run-off per square mile in this vicinity, of which any reliable record has been found, occurred in February, 1886, from about 32 sq. mi. of this same drainage area, when a peak of undoubtedly short duration of about 140 second feet per square mile occurred. The storage below the top of the upstream cofferdam is about 2 500 000 000 gal., the accumulation of which would materially reduce the peak of a short quick flood at the dam.

The gate house is located about 60 ft. upstream from the center of dam and over the stream control conduit. When the embankment of the dam is substantially completed a steel and wooden bulkhead will be built at the upstream end of the stream control conduit and a temporary cofferdam near its lower end. The ordinary dry season flow of the stream will then be carried in a 36-in. steel pipe already laid in the masonry invert of the conduit, while the conduit is being plugged at the gate house and permanent stream control gates, etc., are provided. After the closure of the conduit is completed the 36-in. pipe will be permanently closed and the filling of the reservoir begun. The river control conduit downstream from the gate house will be divided by a horizontal floor about half way up, upon which will be supported the pipes which carry water to the City and below which will flow the water released for use of the mills downstream. The gate house will be equipped with shutters which will provide for drawing either city or mill water substantially from the bottom, from a depth of about 47 ft. or from any depth down to 32 ft. below full reservoir level.

The gate house is also designed to permit the installation of turbines capable of developing the power available from either city or mill water passing through the dam. A Venturi meter for measuring the flow of mill water will be provided near the downstream end of the conduit.

The approach to the spillway of the reservoir is separated from the main dam near its west end by a knoll of ledge rock extending slightly above the top of the dam. A three span reinforced concrete arch bridge about 250 ft. long extends over this arm of the reservoir near the spillway and connects the public road to be built over the dam with the main land. The spillway is a solid masonry structure with a maximum height above rock as indicated by the borings of about 20 ft. and with a gross length of about 440 ft. The net length is about 413 ft. and a platform will be provided about 4 ft. above the crest from which low flashboards can be placed to prevent the loss of water due to wave action when the reservoir is full. The length of spillway is conservatively designed in connection with the great area of the reservoir to take care of any possible floods without unduly raising the water surface. The minimum elevation of the top of the main dam and dike is 13 ft. above flow line of the reservoir and the higher portions of the structure will be built with an allowance for ultimate settlement to this minimum. After falling over the spillway the waste water will be conducted back to the river through an excavated channel about 1 800 ft. long, with the bottom, except near the river, in rock.

It was necessary in order to make a tight dam to provide an impervious cut-off down to rock. A thorough examination indicated that soil and subsoil were the only materials available in sufficient quantity and of dependable uniformity for making a water tight cut-off. The material underlying the subsoil within a practicable distance of the dam is modified glacial drift, very similar in its general characteristics to that encountered in the excavation of the cut-off trench. Its very variable character and the absence from large portions of it of fine materials precluded its use for the core.

A masonry core wall was considered and estimates of cost were made with various designs. It was not deemed good design, on account of the very porous character of the material available for the abutting fill, to depend for watertightness solely upon a non-stable masonry wall, of any dimensions economically practicable, which would be apt to crack under unbalanced pressure, and all designs for masonry cores contemplated a considerable amount of soil and subsoil on one or both sides of the wall. The placing of the soil would be complicated by the presence of the wall and it was concluded that a more satisfactory and more nearly watertight structure could be obtained under the conditions which here prevail by the adopted design, which contains about $2\frac{1}{2}$ times more impervious material than the minimum considered with the masonry wall and has also the advantage of considerable economy over any design of masonry core considered.

The possibilities of hydraulic dam construction were considered at great length, and it was finally decided to require that the impervious core be placed in thin layers (not more than 6 in. after rolling) wet and rolled with heavy rollers. There were several reasons for this conclusion, some of which are as follows:

(1) The excavation and refilling of the deep portions of the core trench with a maximum depth of 80 ft. and a length of over 1 000 ft. had to be done generally below the ground water level and the placing of watertight material under these conditions (such material aggregating about one-fourth the entire amount of this material required in the dam) could, it was believed, be only satisfactorily accomplished by a dry method.

(2) The borrow pits available are so varied in character and contain so many large masses of very coarse material that it was considered unsafe, for the portion of the dam above the ground water level, to depend upon them to produce sufficient fine material to secure a satisfactory watertight core, if deposited by the usual hydraulic method of dam construction.

(3) The soil and subsoil which are being used in the core could, it was believed, even in the upper part of the dam, be as economically placed n position by the dry, as by hydraulic methods, particularly when it is considered that a plant for placing about ¼ of it in the dry would be required for the portion of the dam below ground water level.

(4) All the borrow pit material practically available lies in the valley upstream from the dam and to place it in the dam hydraulically would involve lifting to a maximum height of about 90 ft. The material contains considerable amounts of coarse gravel, cobbles and large boulders which would render pumping very difficult and expensive.

The contractor was given an option in the manner of placing the material outside the soil core and he has decided to place substantially all such material with cars, either deposited in two-foot layers consolidated by heavy hose streams or under some conditions dumped into pools of water.

Some clauses in the specifications for the dam affecting the placing of materials are as follows:

SECT. 11.5. *Impervious Embankment of Soil, Item 11.* Under Item 11 the Contractor shall furnish and place the impervious embankment of soil in the core of the dam and dike and in the upstream face of the cofferdam begun under a previous contract, and elsewhere if directed. Material for this portion of the embankment shall consist of top-soil and subsoil, free from vegetation occurring above the ground surface, containing no masses of roots or individual roots more than 24 in. long or ½ inch in diameter, large stones, porous materials and other undesirable matter. It shall be of acceptably impervious quality. Top-soil containing an excess of organic matter, and silt and muck will not be acceptable. Suitable materials from the excavations may be used in the soil embankment. The remainder shall be obtained from approved locations within the reservoir limits but not closer than 500 ft. to the upstream toe of the dam and dike. Such additional material shall not be included for payment under any excavation item, but all cost of excavating and hauling it to the dam and placing it in the embankment shall be included in the price stipulated for Item 11, however great the haul required. The most convenient areas immediately upstream from the dam from which acceptable soil can be obtained are indicated on Sheets 9, 10, and 11 of the contract drawings. To obtain sufficient acceptable material from easily excavated areas it will be necessary to go beyond the areas shown. Acceptable material for impervious embankment will

generally be found only upon upland areas and many large cleared areas in or near the bottom of the valleys, the most extensive of which are near the main dam, will not be permitted to be used owing to the presence of silt, sand and an excessive amount of organic matter. Material placed under Item 11 shall be rolled in 6-in. layers in the manner specified in Section 11.6. Care should be taken in starting the soil embankment for the core to secure thorough filling of all irregularities in the bottom of the trench and a compact bearing of the soil on the top and edges of the concrete covering of the rockand the cut-off walls, described in Section 17.24, without damaging the masonry. This work will require some hand placing and tamping and shall be done with great thoroughness.

SECT. 11.6. *Rolling.* Refills and embankments of soil placed under Item 11 shall, unless otherwise permitted or required, be deposited in approximately horizontal layers not exceeding 6 in. in thickness when compacted, and unless sufficiently moist as spread shall be wetted in such manner as will secure the uniform moistening of all portions of each layer. The compacted surface shall be acceptably sprinkled immediately before placing each new layer. Each layer shall be rolled by approved rollers having grooved or banded rolls. The heaviest wheels of the roller shall cause a calculated average pressure of at least 30 lb. to the square inch on a bearing surface considered as the width of the roll multiplied by half the arc bounding a segment of the roll, at the bottom of the grooves, having a middle ordinate of one inch. The roller shall pass over every part of each layer that can be traversed by it as many times as may be necessary to thoroughly compact the material. Items 11, and 12 or 13, where contiguous, shall be brought up simultaneously, and the thorough compacting of the soil where it adjoins the pervious materials will be essential to avoid an unsatisfactory softening of the embankment from the use of water in compacting the pervious materials. Portions of the refills or embankments which the rollers cannot reach for any reason, shall be compacted by extra-heavy tampers used energetically, or by other means which will secure a degree of compacting equivalent to that obtained by rolling as specified. At the beginning of each season, the surface of the ground or the enbankment previously placed shall be carefully cleaned and thoroughly rolled before placing any new material, to consolidate any portions that may have been loosened by frost action or otherwise.

SECT. 11.7. *Pervious Filling of Deep Core Trench, Item 12.* The refilling of the deep core trench east of the stream control conduit shall be placed by the method outlined in Section 11, unless an alternative plan be approved. The pervious materials each side of the soil core shall be placed under Item 12 in approximately horizontal layers not over 2 ft. thick, consolidated by the use of jets of water from hose under pressure and by allowing the ground water to rise in the materials. If fine sand is used for this refilling it will probably be necessary to maintain a considerable thickness of material above the ground water level to avoid conditions like quick sand. It is essential that the refilling materials be thoroughly consolidated so as to avoid subsequent settlement, and special care shall be taken to wash earth and sand into all interstices of riprap and other piles of rock fragments on the side slopes of the excavation as the filling progresses.

SECT. 11.8. *Pervious Embankment Above Elevation 195, Item 13.* The pervious refilling and embanking for the dam and dike above Elevation 195 shall, unless an alternative plan be approved, be placed under Item 13 in approximately horizontal layers not over 2 ft. thick and consolidated by the liberal use of jets of water from hose under pressure or by other effective means. The water pressure shall be sufficient to easily move coarse sand. The quantity of water that will be required for this purpose cannot be predicted and may vary materially from time to time, depending on the character of the embankment materials and other conditions. For the purpose of a rough estimate it is assumed that the equivalent of 8 in. depth of water on each 2 ft. layer will be ordinarily sufficient, and much less than this may prove to be satisfactory under certain conditions.

Items 12 and 13 above referred to (Sects. 11.7 and 11.8) are pervious fill both sides of the soil core, and Section 17.24 (referred to Sect. 11.5) is as follows:

SECT. 17.24. *Concrete in Core Trench.* The middle 30 ft. of the bottom of the core trench, excavated and cleaned as specified in Section 4.8, shall be covered or leveled up with concrete to the extent directed from place to place. This work will generally be done before grouting the bottom. The purpose of this concrete is to fill up the larger irregularities of the bottom, to facilitate the grouting and the placing of the soil core, to seal exposed joints and seams in the rock bottom and to form two low cut-offs near either edge of the 30-ft. strip to break the continuity of the contact between the rock and the soil core. Where the bottom is irregular, as was found to be the case for considerable of the portion immediately west of the stream control conduit, the two cut-offs will be provided, but the remainder of the concrete will be placed as best meets the conditions, and the higher projections of the rock bottom, if sound, may be left with no concrete covering.

Construction was begun on a small portion of the Main Dam in January, 1917, under Contract 3, which provided in part for the work necessary to divert the river and which contemplated completion on October 31 of the same year. War was declared in April, 1917, and owing to the delays occasioned thereby, work on this contract was not completed until December 23, 1918. A second contract, No. 11, was entered into in April, 1919, for the completion of the river diversion and for a variety of other work essential to securing the rapid prosecution of construction following the later letting of the major contract. It was expected to complete work on Contract 11 on December 31, 1919, but owing mainly to labor difficulties this contract was not completed until November 1, 1920. With the completion of the stream control work under these two contracts the river was diverted into the horseshoe shaped concrete conduit, 25 ft. wide by 21 ft. 4 in. high and 462 ft. long, built in solid rock across the foundation of the Main Dam. The approach channel lined on bottom and sides with concrete and about 1 000 ft. long and the discharge channel about 200 ft. long completed the river diversion channel, into which the river was turned on November 5, 1919. Portions of the up and downstream cofferdams were built and about 500 ft. of foundation of the dam immediately west of the river diversion conduit was uncovered, the ledge rock grouted and the trench refilled to the original surface with impervious material. The aggregate value of contract work done on the Main Dam prior to the letting of Contract 8, which provides for the completion of this work, was about $278 000.

Contract 8 for the Main Dam and Dike was executed on May 12, 1921. A schedule of the bids received for this contract is appended. The Contractors, Winston & Co., Inc., erected an excellent camp on an area of about 18 acres of sandy ground situated about ½ mile south of the dam. The camp houses a population of about 400 and is supplied with a suitable water supply, electric lights, plumbing for kitchen, laundry, sinks, etc. the drainage from which is satisfactorily disposed of in cesspools; provision

is made for incineration of garbage, and the Kaustine system is used for disposal of human excreta. A thoroughly equipped hospital with attendants is provided at the camp. Some of the sanitary provisions of the contract are as follows:

General Requirements. The Contractor and his employees shall promptly and fully carry out the sanitary and medical requirements as hereinafter described or as may from time to time be promulgated by the Engineer to the end that the health of his employees, of the local communities and of the people using water from the drainage areas affected by his operations may be conserved and safeguarded. The Contractor shall also obey regulations and orders of the properly constituted authorities, Municipal and State. The Contractor shall summarily dismiss and shall not again engage, except with the written consent of the Engineer, any employee who violates the sanitary and medical requirements; nor shall any person be employed, without the written consent of the Engineer, who is known to have violated the sanitary regulations on other works of the City.

Inspection. The Engineer shall have the right, in order to determine whether the requirements of this contract as to sanitary matters are being complied with, to enter and inspect any camp or building or any part of the works, and to cause any employee to be examined physically or medically or to be vaccinated or otherwise treated; also to inspect the drinking water and food supplied to the employees.

Quarters and Stables. The Contractor shall provide suitable and satisfactory buildings for the housing, feeding and sanitary necessities of the men, and suitable stabling for animals, employed upon the work. All buildings for these or kindred purposes shall be built only in accordance with approved drawings and specifications. All houses occupied by employees shall be thoroughly screened to exclude mosquitoes and flies. The quarters for the men shall be grouped in properly arranged camps located downstream from the proposed dam. The Contractor shall submit the locations proposed for his camps, buildings, and sanitary works to the Engineer for approval, whether located on the land of the City or elsewhere, and no such structures shall be erected until such approval shall have been obtained.

Sanitary Conveniences and Disposal of Excreta. Buildings for the sanitary necessities of all persons employed on the work, beginning with the first men employed to build camps or for other preliminary operations, shall be constructed and maintained by the Contractor in the number, manner and places ordered. These conveniences shall be of an approved chemical or an approved incinerator type, except that closets having watertight removable receptacles may be used in special cases, if and as permitted. Satisfactory precautions shall be taken to render the interior of the closest inaccessible to flies. The requirements for sanitaries in any locality shall be on a basis of not less than one unit for each 20 persons, including both those on duty and those in camp off duty, who are dependent on the sanitaries in the locality in question; it being further stipulated that the required number are always reasonably near the work, and that incinerators, if used, are always in sufficient number in any locality to permit a reasonable proportion to be out of service for the daily incineration of their contents. The Contractor shall rigorously prohibit the committing of nuisances upon land of the City or adjacent private property.

Medical and Surgical Attendance. The Contractor shall retain the services of one or more acceptable, qualified physicians, who shall reside at the work and have the care of his employees, shall inspect their dwellings, the stables and the sanitaries as often as required, and shall supply medical attendance and medicines to the employees whenever needed. The Contractor shall provide at the works from approved plans, a building

properly fitted for the purpose of a hospital, with facilities for heating and ventilating in cold weather, and for screening and ventilating in warm weather. This hospital shall be provided with all necessary medicines and medical appliances for the proper care of the sick and injured. At such places as directed all articles necessary for giving "First aid to the Injured," shall be provided.

Medical Supervision of Employees; Reports. The medical supervision of the Contractor over his employees shall extend to the physical and medical examination of all applicants for employment, in order to prevent persons having communicable diseases from becoming connected with the work, and the Contractor shall employ only persons shown by such examination to be free from communicable diseases. Any employee having a communicable disease shall be removed, when and as directed, to an approved permanent hospital. Whenever, in the opinion of the Engineer, it is necessary for the protection of the public health or the health of the employees, the Contractor shall remove any employee either to a hospital or permanently from the work or camp. Once each week, if required, the Contractor shall give the Engineer, in such detail as may be prescribed from time to time, a written report, signed by a physician in regular attendance, setting forth clearly the health condition of the camp or camps and of the employees. If any case of communicable disease be discovered, or any case of doubtful diagnosis, it shall be reported at once to the Engineer, by telephone or messenger, and confirmed in writing.

Domestic Water Supply. The water furnished by the Contractor shall include a sufficient supply of drinking water of acceptable quality for all his employees, to be obtained from approved sources. He shall provide ample bathing and clothes-washing facilities for his employees and sufficient water of acceptable quality therefor. If any water supply for domestic use should become contaminated, the contractor shall promptly provide a new supply from an approved source and abandon the contaminated supply, or shall provide works for purifying the contaminated water, when and as ordered.

Treatment of Drainage. Drainage from kitchens, laundries, sinks, baths, and stables shall be conducted in tight drains or other satisfactory conveyors to approved points of disposal where it will filter through the ground before entering any watercourse.

Disinfectant and Fumigation. The Contractor shall supply corrosive sublimate, quick lime, sulphur and other disinfectants and fumigants in ordered quantities, and perform the labor necessary to apply these materials when and as directed in disinfecting and fumigating camp and other buildings and disinfecting stables or grounds.

Garbage Disposal. Garbage, both liquid and solid, shall be promptly and satisfactorily removed from the building and immediately placed in approved tight receptacles of sufficient capacity of about one day's ordinary production. At least once in every twenty-four hours all such garbage shall be incinerated or otherwise thoroughly and satisfactorily disposed of in an approved manner.

Care of Stables. Manure will not be permitted to accumulate upon the premises but must be removed daily to an approved distance or daily incinerated. Removable stall racks shall be provided to permit thorough cleaning.

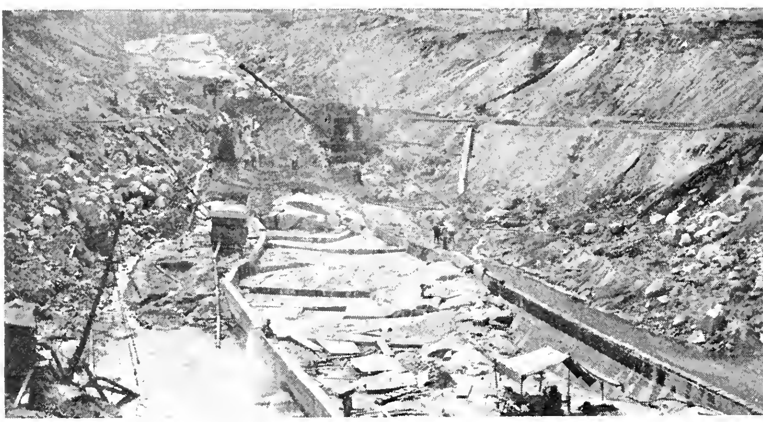
Main Dam, Scituate Reservoir.

Rock uncovered in bottom of core trench east of stream control conduit, shown towards the left. Upstream cofferdam shows at the top towards the right. Low point of excavation is about 70 feet below former river bed. Contract 8, June 1, 1922.

MAIN DAM, SCITUATE RESERVOIR.

Excavation for deep portion of core trench, looking northeast showing upstream cofferdam at top, and track system with switchback. Contract 8, June 1, 1922.

The construction of a standard gage railroad about 2.3 mi. long, connecting the N.Y., N.H. & H. Railroad at Jackson with the dam, was completed on August 13, 1921. A high tension power line about 1 mile in length connecting the Narragansett Electric Lighting Company's line with the work at the dam was completed September 28, 1921. Electric current is used for lighting, pumping, for operating machine shop and saw mill and for a variety of other purposes. The contractor's equipment in use at the dam consists mainly of 3-ft. gage cars and locomotives, large and small steam shovels, small drag line excavators, steam rollers, one 12-ton traveling cable way, crossing the deep excavation transversely, directly connected electrically driven pumps with a total capacity of about 9 million gallons daily against a lift of about 80 ft., pumps, tanks and piping for water supply, compressor, grouting machine, bottom dumping wagons, mules and the usual rock drills and small tools. The excavation for the deepest portion of the core trench was completed, the foundation grouted



MAIN DAM, SCITUATE RESERVOIR.

Core trench looking west towards stream control conduit. Sump in foreground is deepest point of foundation, about 80 feet below original surface. Pump machine shows under canvas covering in right foreground. Soil core being started part way up slope. Contract 8, August 14, 1922.

and refilling begun in August, 1922. In order to keep the deep portion of the core trench unwatered, extensive pumping was necessary as shown in a later tabulation. The average side slopes of the excavation for the deep portion of the cut-off trench are about 2 horizontal to 1 vertical and the heavy shovels were operated when necessary, and without serious difficulty, in very fine sand with the line of saturation practically at its surface. The material in the excavation was very variable in stratification and unwatering was accomplished by open sumps below the general level of the excavation in locations where the material was coarse and from which the

water was pumped. In one instance the excavation of a sheeted pump well through fine sand to coarse underlying strata shown by the borings was attempted and after a considerable expenditure of time and money was given up because the running in of the sand rendered its excavation practically impossible by the ordinary methods which were available. This same sand, when relieved of upward water pressure by tapping the coarse material at some point below it, stands up at a steep slope. Had the very fine portions of the materials to be excavated been deposited in horizontal strata, more difficulty would have been experienced in excavation, but with this material existing in pockets, even though some of them were very large, ittle difficulty was experienced, with the aid of the preliminary borings in selecting satisfactory sites for sumps. The prosecution of the work

MAIN DAM, SITUATE RESERVOIR.

Looking east along portion of core trench west of stream control conduit, showing placing of soil core. Contract 8, August 14, 1922.

has demonstrated fully to the writer that, with the material varying from very fine sand, extremely active under water pressure, to gravel and with boulders of all sizes up to several yards in volume, the method of excavation used is the best and most economical.

The experience so far gained has demonstrated that a rolled sand and gravel embankment in thin layers either side of the soil core would have been prohibitive in cost owing to the boulders in the material available.

The following tabulation gives various progress data regarding the excavation and pumpage from the deep portion of the dam foundation.

SCITUATE DAM. PUMPAGE AND EXCAVATION FOR DEEP PORTION OF FOUNDATION.

Date.	Average Weekly Pumpage Million Gals. Daily.	Vertical Projection of Area of Cut Below El. 200 (Approximate Original Ground Water Level) Sq. Ft.	Maximum Depth of Cut Below Elevation 200, Except at Sump Ft.	TOTAL EXCAVATION (Contract 8) Including 30 000 Cu. Yds. above Elevation 200 Cu. Yds.
Oct. 10, 1921	. .	8 800	12	62 600
15	1.5	. .	. .	. .
22	1.3	. .	. .	. .
29	1.7	. .	. .	. .
Nov. 5	1.7	. .	. .	. .
10	. .	12 700	24	80 690
12	1.9	. .	. .	. .
19	2.1	. .	. .	. .
26	2.2	. .	. .	. .
Dec. 3	2.4	. .	. .	. .
10	2.6	16 700	24	125 600
17	2.9	. .	. .	. .
24	3.0	. .	. .	. .
31	3.1	. .	. .	. .
Jan. 7, 1922	3.1	. .	. .	. .
10	. .	19 900	31	151 000
14	3.7	. .	. .	. .
21	4.1	. .	. .	. .
28	3.4	. .	. .	. .
Feb. 4	3.6	. .	. .	. .
10	. .	25 300	36	181 900
11	3.7	. .	. .	. .
18	3.7	. .	. .	. .
25	3.8	. .	. .	. .
Mar. 4	3.8	. .	. .	. .
10	. .	30 600	41	208 800
11	3.9	. .	. .	. .
18	3.9	. .	. .	. .
25	4.0	. .	. .	. .
Apr. 1	4.2	. .	. .	. .
8	4.1	. .	. .	. .
10	. .	34 400	45	230 400
15	4.8	. .	. .	. .
22	4.5	. .	. .	. .
29	3.9	. .	. .	. .
May 6	3.7	. .	. .	. .
10	. .	38 600	54	248 300
13	4.5	. .	. .	. .
20	4.7	. .	. .	. .
27	4.6	. .	. .	. .
June 3	4.3	. .	. .	. .
10	4.4	41 300	64	263 600
17	4.2	. .	. .	. .
24	4.3	. .	. .	. .
July 1	4.3	. .	. .	. .
8	4.3	. .	. .	. .
	. .	43 300	71	272 200
15	4.6	. .	. .	. .
22	4.4	. .	. .	. .
29	5.6*	. .	. .	. .
Aug. 5	6.1*	. .	. .	. .
10		44 400	74	280 300
12	5.4	. .	. .	. .
19	4.6	. .	. .	. .
26	4.9	. .	. .	. .
Sept. 2	5.0	. .	. .	. .

* Probably too large, as water pumped contained much fine sand and quantity is based on pump hours.

Preparation of Rock Foundation. After the earth and boulders have been removed from the core trench the top of the ledge rock is excavated to the extent directed without the use of explosives, the object being to remove so far as possible all seamy, broken and disintegrated rock such as would permit the flow of water from the upstream side of the dam after completion. The entire width of exposed rock bottom is then thoroughly cleaned and scrupulously freed from all dirt, gravel, boulders, loose fragments, etc., streams of water under sufficient pressure, stiff brushes, hammers and other effective means being used to accomplish this cleaning. The full ordered width of the bottom of the trench then receives special treatment by raking out all remaining seams and cavities and filling them with grout or mortar.

The middle portion of the core trench about 30 ft. in width is then covered or leveled up to the extent directed from place to place with concrete, the purpose being to fill the larger irregularities of the bottom, to facilitate the grouting and placing of the soil core and to seal exposed joints and seams in the rock bottom. There are also generally two low concrete cut-off walls near either edge of the 30-ft. strip which break the continuity of the contact between the rock and the soil core. The rock bottom exposed is generally very irregular and the concrete and the walls are placed so as to best meet the conditions encountered, there frequently being no concrete over high projections of the bottom and the concrete walls being omitted in places where they would serve no useful purpose. Sometimes before and sometimes after, placing the concrete, holes are drilled for grouting.

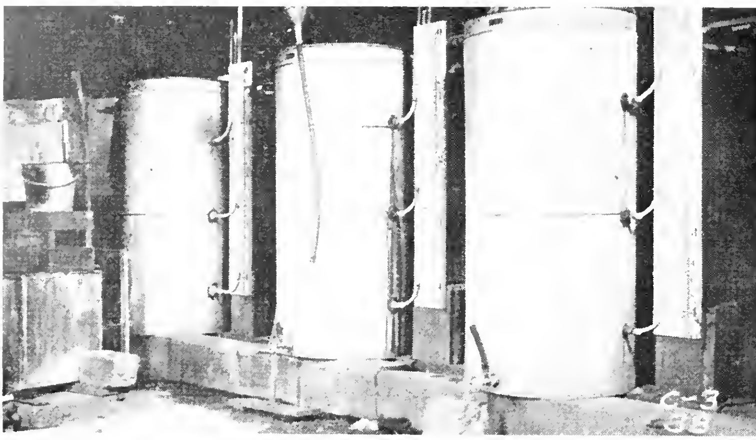
These holes generally do not extend more than 20 ft. into the rock but occasionally holes for test grouting and for other purposes are drilled to considerably greater depths.

Steel pipes with standard couplings, plugs and other fittings, are set in the rock or masonry where required so as to give water-tight joints to which the grouting machine is connected. The apparatus for mixing and placing grout is mounted on wheels with a direct connected engine, and consists essentially of an air-tight chamber in which the grout is mechanically stirred and from which it is forced by air pressure into the voids. The grout is generally placed under low pressure, much of it at about 5 lb. to the square inch and little exceeding 20 lb. After a section of the cut-off trench has been grouted, deeper holes, generally 30 to 35 ft. in depth, are drilled at occasional points to test the completeness of the previous grouting. About half of the foundation for the dam has already been satisfactorily grouted.

Tests of Materials for Core. Tests were begun in 1917 of materials available for the impervious core of the dam. Those tests demonstrated top-soil and subsoil to be entirely satisfactory and were in close agreement with an extensive series of tests made upon top-soil by the Metropolitan Water Works of Massachusetts some 25 years ago, following which top-

soil was depended upon solely for watertightness in the construction of the north and south dikes of the Wachusett Reservoir. Experiments were made of the rate of percolation through large cans and through small cans, the apparatus for each of which is shown on accompanying photographs.

For the large can experiments, the apparatus consists essentially of four circular galvanized iron tanks each 2 ft. $4\frac{1}{4}$ in. in diameter and 5 ft. high, the sectional area being 1/10 000 of an acre. Near the bottom was a sill-cock. On the side of the tank were three perforations spaced 18 in. vertically on centers, with which were connected on the inside perforated



Apparatus for Large Can Percolation Test.

pipes traversing the material under test in the tank and on the outside glass gages. A waste vent was provided near the top of the tank. The tanks were filled in the following manner: At the bottom was placed a 5-in layer of pervious material graduating up from coarse gravel at the bottom to medium sand at the top. Directly on top of this was placed the material to be tested. This material had a total depth, or thickness, of 3 ft. 8 in. and on top of this was placed a 1-in. layer of coarse sand. The material to be tested was put into the tank in quantities such that with energetic tamping it was consolidated into layers from $1\frac{1}{2}$ to 2 in. in thickness. Water was let into the tanks from the bottom by attaching to the sill-cock a piece of rubber garden hose connecting with a funnel suspended so as to give a moderate head. As it appeared advisable this funnel was raised until water appeared on the surface of the sand near the top of the tank. Water was then admitted to the open top of the tank, the level being kept constant by an overflow. The rubber hose was then removed from the sill-cock and the water allowed to percolate through the material as it would. It was the endeavor, however, to keep the flow such that the loss of head between the top and bottom perforated pipes would be approximately three feet. To accomplish this there was attached to the sill-cock

a short piece of garden hose, the end of which was raised or lowered as desired, thereby reducing or increasing the total effective head. The material under observation in the tanks was traversed at three places by perforated pipes leading to the connections at the sides of the tank and through them connected with glass tubes placed against a gage board. The perforations in these pipes were about ¼ in. in diameter and spaced in two diametrically opposite straight lines at about three inches center to center. At first these pipes were wrapped with a copper mosquito netting having 8 or 10 meshes to the inch, but upon disassembling the first tank

Apparatus for Small Can Percolation Test.

the pipes were found nearly filled with material. Thereafter each pipe was covered with copper screening of 100 meshes to the inch carefully soldered to the pipe, with the result that practically no material entered the pipes. Pieces of rubber garden hose connected the pipes with the stiff connections through the wall of the tank. These connections were in turn joined to the glass tubes by white rubber tubing, care being taken that it made a sharp slope upward to the bottom of the glass tube. This was calculated to permit easy egress for air bubbles and was adopted only after considerable attention had been given to the removal of air from the pipes. In placing each perforated pipe in the tanks the material was tamped up to a slightly greater height than that required for the pipe. A groove was then

dug out of the compacted material, the pipe was put in place and leveled up and then the material carefully tamped around and over it. Difficulty was experienced in keeping these pipes level, but that is not felt to be a serious defect. The gage glasses were about $2\frac{1}{2}$ in. in diameter. One gage board served for all three tubes in each tank and was graduated to hundredths of a foot with the zero at the top and approximately at the surface of the water in the tank. The total loss of head at the different levels in the tank was therefore easily read at a glance.

All materials were used just as dug from the fields except for thorough mixing and the addition at times of water. Mixing consisted of the shoveling from the pit into the wagon, the shoveling out of the wagon and at least three complete turns on the floor. No frozen material was used and all lumps were carefully broken down. In the case of the gravelly material used in Experiment 4-C great care was taken to see that the stones did not sort themselves out in the handling. In packing all the tanks it was the practice to have the porous layer at the bottom of the tank full of water before the test material was placed to any extent. This was to do away with the considerable pocket of air that could have been moved only upward through the entire mass of the material or possibly through the three perforated pipes.

Considerable difficulty was experienced from time to time throughout the experiments with entrained air and it is probable that some of the otherwise unexplainable differences in results may be due to entrained air. The time available and the limitations of the apparatus did not permit pursuing to a final solution all the problems which arose. Difference in temperature was also important and the results have been reduced finally to a temperature of 50°F. There are doubtless other factors which may enter into a more refined consideration of the problem, such as atmospheric pressure which was considered but was disregarded. The results are believed to be sufficiently accurate for the purpose intended and are as good as it appeared practicable to obtain unless apparatus with very great refinement is used.

The small cans are about 9 in. high and 6 in. in diameter. The bottom of the can is covered with a half inch layer of porous sand. The material to be tested is then tamped in thin layers upon this to a total depth of 6 in. and the top covered with porous sand $\frac{1}{2}$ in. deep. A small hole through the bottom of the can into which is threaded a loose cord to control the drip provides the means for collecting the percolation and conducting it as required into a glass graduate. After filling, the cans were placed in a tub of water and the material saturated through the hole in the bottom in order to expel the air. In some of the experiments a device was used to increase the pressure while filling the small cans with water by sealing the tops of the cans and creating a partial vacuum on top of the sand, thus reducing the time of filling. Following saturation the cans were removed from the tub and filling over the top was begun. The arrangements for

insuring a constant head upon a series of tanks are indicated upon Plate IV and accompanying photograph. Parallel tests of the same materials in both large and small cans indicated a sufficiently close agreement to demon-

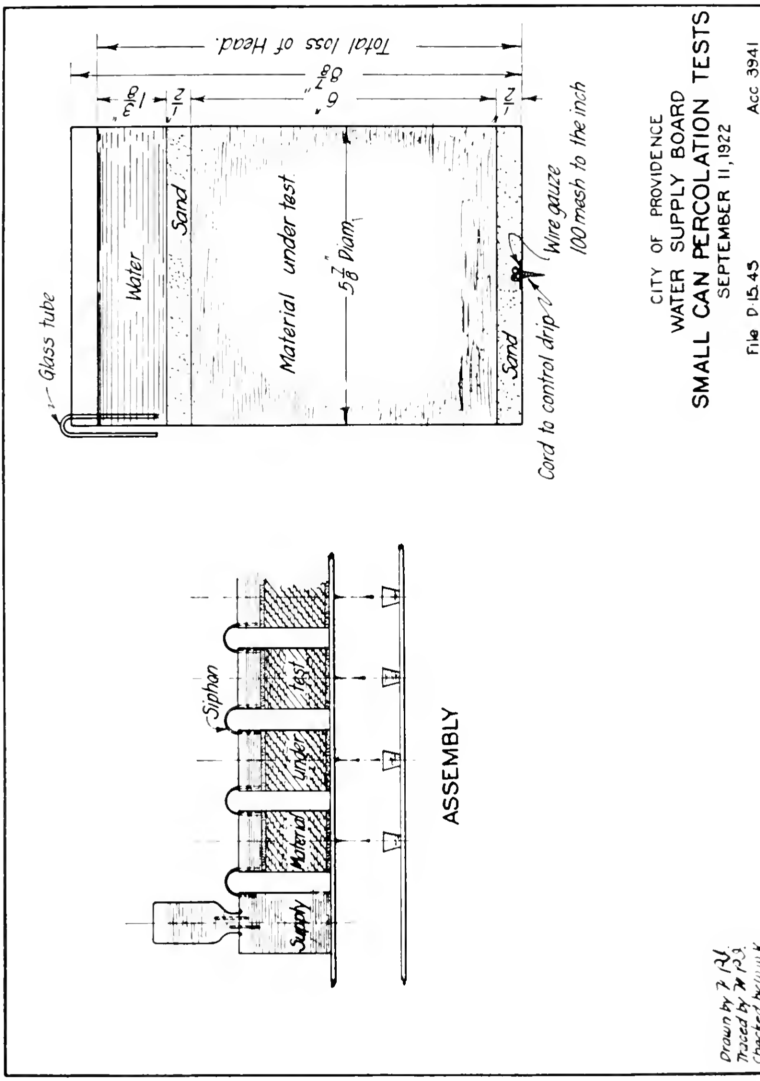


Plate IV.

strate that the results from small can tests could be depended upon to indicate relative porosity within the limits of accuracy required. Tests with the small cans are therefore being kept up of the materials for core as they are being collected in the field and as they are being placed in the core.

Results of Tests Made Prior to Adoption of Design of Dam Mainly Large Can Tests.

There are considerable masses of very fine sand in strata and pockets near the dam and the finest of these materials were also tested. The results plainly divided themselves into two classes:

(1) The fine sands, which permit a relatively large rate of percolation.

(2) The top soils and subsoils, which have a high degree of impermeability.

A further test of the fine sands was made by separating that portion only which passed a 200 mesh sieve.

That the temperature of the water has a great influence on the rate of percolation through sand has been well demonstrated in other experiments. In these experiments it would perhaps have been well if continuous records had been made of the temperature of both the water and the air but this was not done. A dairy thermometer was provided and read at frequent intervals and at times more elaborate observations as to the effect of the temperature were attempted but no definite results were achieved. It is undoubtedly true also that the barometric pressure has an appreciable influence but this has been entirely neglected.

The temperature of the air or water in the interior of the tank at any point or time was not determined. That changes in the interior of the tanks are not so marked as those in the air surrounding them or in the water on top of them, and that there is an appreciable lag, is probably true. Yet these outside changes form the only data available from which to make correction. Measures of flow accumulated throughout the night have been considered as check measurements only and have not been corrected for the reason that the night temperatures were not known. That this knowledge is necessary is shown by the fact that in every case the flow decreased at night due to the lower temperature.

In general two or perhaps three measurements were made each day, the total time between say nine and three o'clock, being consumed in the combined measurements. At the same time the temperature of the water standing in the tanks was observed and it is from these temperatures, averaged for the interval of each measurement, that the corrections are figured. That they are not completely satisfactory may be accounted for generally by an appreciation of the probable amount of the lag and the influence of this lag upon both the viscosity and the air entrained in the pores. In some of the early work the temperature of the water was not closely observed and in these cases the atmospheric temperature has been made use of.

The correction for temperature is figured by the formula derived by Allen Hazen, Past President of this Association, and stated in the *Annual*

Report of the Massachusetts State Board of Health for 1902, page 541. For application to the problem in hand it may be expressed as follows:—

$$\text{Rate at } 50°\text{F} = \text{Observed Rate } \frac{(60)}{\text{T}+10}, \text{ T being the observed temperature.}$$

As stated previously the value of T is more or less indeterminate but has been taken usually as that of the water standing on top of the tank.

Another uncertain element and perhaps the most uncertain of all, is in the difficulty of securing uniformity in placing material in the tanks. This probably accounts for much of the variations in duplicate tests of samples of the same material. Tamping and moisture control are most important. The tamping was done with a light iron rammer about 4 in. in diameter. It was lifted each time a comfortable height, about 9 in., and forcibly pounded down. A large heavy rammer was attempted but it was discarded almost at once as it jarred the tanks, even the adjacent ones, to such an extent that it was felt that possibly it was doing more damage than good. Under its use too the material would creep and break up around the edges. A uniform working all over the surface was decided upon as being best.

The most satisfactory condition and the one aimed at in all cases seemed to be in that middle zone where the material was damp and yet not too wet, where it would pack without breaking up or creeping and where the feeling on the handle of the rammer was that of a firm refusal with no "give" either of a dry crumbling or a soft mushy nature. Generally speaking it was felt to be in satisfactory condition when the surface after tamping became moist enough to feel "tacky". This could readily be detected by tapping with the feet when the tacky condition could be both heard and felt.

It was suggested that tamping in this condition brought about a separation of the materials with the result that the very finest particles were segregated into a film over the entire surface where they would form a layer so dense as possibly to preclude any percolation through it except where it might be imperfect or broken. In the tanks first packed and first dug out a tendency to such a segregation was shown by the fact that at places the layers were plainly to be observed and could be separated into definite planes but no tendency towards the formation of a film could be definitely observed. To obviate the possibility of this thereafter the surface of each layer, after being tamped, was scratched with a fine rake.

A variety of other interesting and, in some cases, not readily explainable phenomena developed during the progress of the tests but space does not permit of detailing them here. They are not believed to have an important bearing on the results and more refined apparatus would be necessary to account fully for many of them.

Results of large can experiments are given in the following tabulation. The difference between top-soil and subsoil can perhaps be best appreciated by quoting the definition given in the specifications for the Main Dam:

"Soil shall mean the material composing the surface layer of the ground which has been so affected by vegetable growth that it contains a considerable amount of organic matter" — page 17, Contract 8, etc.

Experiment.	Duration Days.	Material.	Rate of Percolation.	Per cent Passing 200 Sieve.	Per cent Organic Matter Loss on Ignition.
1 A	50	Mixed top-soil and subsoil	*15 300	†58.1	3.67
2 A	32		8 600		
1 B	40	Subsoil	21 350	35.4	3.32
2 B	38	Subsoil and discolored fine sand	3 200	38.1	3.46
3 B	38	Mixed top-soil and subsoil	1 500	56.9	7.00
4 B	30	" " " "	2 200	60.4	5.21
1 C	11	Topsoil (Grass roots in)	10 800	38.6	5.74
2 C	11	" (" " out)	10 000	36.9	4.80
3 C	18	Fine discolored sandy subsoil	11 700	48.0	4.12
4 C	25	Gravelly subsoil	6 300	22.6	3.01
3 A	15	Superfine white sand	514 000	26	0.0
4 A	10		387 000		

Tests in small cans of material tested in large can experiments 3A and 4A above gave a rate of 579 000 gal. per acre as compared with 514 000 and 387 000. A test of the portions of this material passing a 200-mesh sieve gives 200 500 gal. per acre. Two tests each in small cans of material tested in large can experiments 1B and 2B gave following results:

1B Large Can	21 350‡
Small can No. 5	4 500
Small can No. 6	3 200
2B large can	3 200
Small can 13	3 800
Small can 14	3 200

Following is a tabulation of small can tests made during construction, mainly to demonstrate the quality of material proposed for or used in the core. Tests run from 6 to 10 days.

Rejected or For Other Reasons Not Used.

Date.	Percolation.	Material.
July — Aug. 1920	53 000	Coarse sand mixed with top soil in core.
July — Aug. 1920	115 000	Discolored coarse sand under top soil in core.
July — Aug. 1920	15 000	Very fine sand (rock flour) occurring in a thin streak in core trench — not available for and not used in core.
July — Aug. 1920	8 300	Dark top soil and subsoil with some silt. Very little used in core.

*Gallons per acre per day figured as for 1 : 1 slope, from data on the total loss of head and corrected for temperature.

†Only that portion of material passing No. 10 sieve considered.

‡This was the first large can to be filled with soil and the rate of percolation is undoubtedly higher than would have obtained in later work after experience had been gained in the consolidation of the material.

Aug. 1921	33 000	Very fine white sand which occurred in small quantities in cut-off trench.
Aug. 1921	42 000	Coarse sandy subsoil.
Nov. 1921	25 000	Coarse sandy subsoil.
April 1922	20 000	Coarse sandy subsoil.
April 1922	13 000 8 000	Very fine sand below subsoil.
May 1922	6 000 2 200	Very fine sand below subsoil.
May 1922	4 000	Material under subsoil.
Aug. 1922	21 000	Retest of same material as above (first test appears to have been in error.)
Aug. 1922	66 000 65 000	Coarse loamy material from storage pile.

Acceptable and Used or to be Used in Core.

Aug. 1921	10 000	Top soil and subsoil.
Aug. 1921	11 000	Subsoil.
Sept. 1921	9 000	Subsoil.
Sept. 1921	4 000	Subsoil
Sept. 1921	9 000	Subsoil.
Sept. 1921	3 000	Subsoil.
Oct. 1921	1 200	Top soil and subsoil from storage pile.
Oct. 1921	2 000	Top soil and subsoil from storage pile.
Oct. 1921	3 000	Top soil and subsoil from storage pile.
Nov. 1921	5 300	Subsoil.
April 1922	12 000	Top soil.
April 1922	17 000	Subsoil.
April 1922	9 000	Top soil.
April 1922	18 000	Subsoil
April 1922	40 000	Top and subsoil. This is evidently a poor test as appearance of material is excellent and is similar to that tested in following two tests.
April 1922	2 000 11 000	Top soil and subsoil from storage pile.
April 1922	1 400 1 300	Top soil and subsoil from storage pile.
May 1922	400 1,400	Top soil and subsoil from storage pile.
May 1922	300 900	Top soil and subsoil from storage pile.
May 1922	1 300 900	Top soil and subsoil from storage pile.
May 1922	1 200 1 000	Top soil and subsoil from storage pile.
May 1922	1 700 1 400	Top soil and subsoil from storage pile.
May 1922	6 300 1 600	Subsoil in place.
Aug. 1922	2 400 525	Top soil and subsoil from storage pile.

Aug. 1922	1 200 14 000	Top soil and subsoil from storage pile.
Aug. 1922	270 700	Top soil and subsoil.
Aug. 1922	680	Top soil and subsoil from storage pile.
Aug. 1922	2 600 1 800	Black top soil.
Aug. 1922	2 200 2 600	Top soil and subsoil.
Aug. 1922	11 000 13 000	Top soil.
Aug. 1922	5 000 5 000	Subsoil underlying above top soil.
Aug. 1922	4 000 2 000	Mixture of above top and subsoils.

SAMPLES OF MATERIAL ACTUALLY TAKEN FROM SOIL CORE AFTER PLACING.

			Station.	Elevation.
Aug. 17, 1920	2 000	Core of Dam	22+00	216.5
Aug. 17, 1920	2 400	Core of Dam	21+00	209.0
Aug. 17, 1920	2 200	Core of Dam	20+00	207.0
Aug. 25, 1920	2 400	Core of Dam	21+50	213.1
Aug. 25, 1920	1 800	Core of Dam	20+50	211.0
Aug. 25, 1920	1 800	Core of Dam	19+50	206.3
Aug. 30, 1920*	9 000	Core of Dam		
Sept. 1, 1920	2 000	Core of Dam	20+00	213.0
Sept. 1, 1920	2 000	Core of Dam	21+00	213.5
Sept. 1, 1920	2 000	Core of Dam	22+00	216.0
Sept. 11, 1920	2 000	Core of Dam	20+50	216.4
Sept. 11, 1920	2 000	Core of Dam	21+50	215.8
Sept. 11, 1920	3 000	Core of Dam	22+50	219.6

Mechanical analyses were made of materials tested in the large cans and also of those used in a considerable number of the small can experiments. In some of the later work the elutriation method has been used to determine the smaller grain sizes. It has not yet been possible to make positive deductions from these tests, which are being continued.

It is the writer's tentative opinion that the sizes and proportions of the grains account for the high degree of imperviousness in soils and that the organic content has little if any relation thereto. It is probable that experiments of a more refined character may be required to establish the relation between imperviousness and the sizes and proportions of the particles.

The loss of water through the dam as designed, if core materials having an average rate of percolation of 10 000 g.d. were used, would be

*This sample was of a very small quantity of material delivered at core the appearance of which indicated it to be of doubtful suitability for which reason the test was made. The sample was obtained by scraping from the surface what appeared to be the most pervious material which could be found. This is believed to be the most pervious material so far used in the core and as the quantity used is negligible an average porosity is represented by the other samples

City of Providence, Water Supply Board, Scituate Reservoir. Contract 8, Main Dam and Dike.

Canvass of Bids Opened April 27, 1921. Contract Executed with Winston & Co., Inc., May 12, 1921.

			*Winston & Co., Inc., 240 Fair Street, Kingston, N. Y.		Wilson & English Construction Co., 50 Church Street, New York City, N. Y.		Rinehart & Dennis Co., Inc., National Bank Bldg., Charlottesville, Va.		C. W. Blakeslee & Sons, 58 Waverly St., New Haven, Conn.		E. W. Foley Const. Corp., 34 Pine St., New York, N. Y.		Mellon Stuart Company, 2112 Oliver Building, Smithfield St., Pittsburg, Penna.		Arthur G. McKee & Co., 2422 Euclid Ave., Cleveland, Ohio.	
Item.	Description.	Quantity and Unit.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.	Price.	Amount.
1	Clearing	200 Acres	$65.00	$13 000	$250.00	$50 000	$200.00	$40 000	$160.00	$32 000	$225.00	$45 000	$180.00	$36 000	$136.50	$27 300
2	Grubbing	10 Acres	200.00	2 000	300.00	3 000	300.00	3 000	300.00	3 000	175.00	1 750	200.00	2 000	205.25	2 052
3	Removal of soil	40 000 Cu. yd.	0.90	36 000	1.50	60 000	1.00	40 000	1.00	40 000	1.50	60 000	1.25	50 000	1.02	40 800
4	Earth excav. in open trench for dam above El. 195, etc.	260 000 Cu. yd.	0.85	221 000	0.90	234 000	1.00	260 000	1.20	312 000	1.40	364 000	0.76	197 600	0.52	135 200
5	Earth excav. in open trench for dam between El. 195-160.	220 000 Cu. yd.	1.90	418 000	1.00	220 000	1.25	275 000	1.45	319 000	3.25	715 000	1.43	314 600	0.60	132 000
6	Earth excav. in open trench for dam below El. 160	60 000 Cu. yd.	2.40	144 000	1.90	114 000	2.00	120 000	2.05	123 000	4.00	240 000	2.69	161 400	1.66	99 600
7	Earth excavation in sheeted trench	1 000 Cu. yd.	2.90	2 900	15.00	15 000	5.00	5 000	10.00	10 000	15.00	15 000	9.50	9 500	8.20	8 200
8	Rock excavation where blasting is permitted	50 000 Cu. yd.	2.95	147 500	3.50	175 000	3.00	150 000	3.00	150 000	5.00	250 000	3.10	155 000	3.47	173 500
9	Rock excavation where blasting is not permitted	7 000 Cu. yd.	5.90	41 300	8.00	56 000	5.00	35 000	10.00	70 000	9.00	63 000	6.00	42 000	7.30	51 100
10	Pumping from core trench of main dam	Lump sum	....	59 000	..	75 000	.....	200 000		120 000	.	100 000		500 000		206 000
11	Refilling and embanking of soil in 6-inch layers	600 000 Cu. yd.	1.00	600 000	2.00	1 200 000	1.50	900 000	2.25	1 350 000	2.00	1 200 000	1.82	1 092 000	2.25	1 350 000
12	Refilling of pervious materials for dam below El. 195	150 000 Cu. yd.	0.65	97 500	1.00	150 000	1.00	150 000	0.70	105 000	0.60	90 000	1.20	180 000	1.15	172 500
13	Refilling and embanking of pervious materials above El. 195	2 000 000 Cu. yd.	0.49	980 000	0.65	1 300 000	0.75	1 500 000	0.55	1 100 000	0.65	1 300 000	0.99	1 980 000	1.04	2 080 000
14	Miscellaneous refilling and embanking	30 000 Cu. yd.	0.80	24 000	1.00	30 000	1.50	45 000	0.90	27 000	1.10	33 000	2.40	72 000	1.70	51 000
15	Soil dressing	75 000 Cu. yd.	0.80	60 000	1.75	131 250	1.50	112 500	2.00	150 000	1.40	105 000	1.65	123 750	3.07	230 250
16	Grassing	40 Acres	50.00	2 000	200.00	8 000	50.00	2 000	120.00	4 800	80.00	3 200	175.00	7 000	136.50	5 460
17	Concrete	15 000 Cu. yd.	7.20	108 000	9.00	135 000	10.00	150 000	14.10	211 500	11.00	165 000	12.00	180 000	18.00	270 000
18	Concrete	5 000 Cu. yd.	14.00	70 000	15.00	75 000	16.00	80 000	17.50	87 500	16.00	80 000	14.00	70 000	26.00	130 000
19	Reinforced concrete	1 500 Cu. yd.	30.00	45 000	20.00	30 000	20.00	30 000	32.00	48 000	28.00	42 000	22.00	33 000	39.00	58 500
20	Surface finish of concrete by scrubbing with acid	5 000 Sq. ft.	0.10	500	0.10	500	0.50	2 500	0.20	1 000	0.20	1 000	0.19	950	0.08	400
21	Surface finish of concrete by tool dressing	10 000 Sq. ft.	0.20	2 000	0.15	1 500	0.80	8 000	0.55	5 500	0.25	2 500	0.30	3 000	0.16	1 600
22	Surface finish of concrete by granolithic finish	3 000 Sq. ft.	0.10	300	0.10	300	0.50	1 500	0.20	600	0.35	1 050	0.20	600	0.27	810
23	Reinforced concrete ladders	100 Lin. ft.	4.00	400	10.00	1 000	10.00	1 000	2.50	250	3.50	350	2.00	200	2.70	270
24	Grout	5 000 Cu. yd.	5.80	29 000	4.00	20 000	10.00	50 000	10.00	50 000	9.00	45 000	12.00	60 000	4.00	20 000
25	Eight-inch vitrified pipe	2 500 Lin. ft.	1.00	2 500	1.00	2 500	1.50	3 750	1.00	2 500	1.25	3 125	1.25	3 125	1.36	3 400
26	Twelve-inch vitrified pipe	250 Lin. ft.	1.50	375	1.50	375	3.00	750	1.25	312	2.00	500	2.50	625	2.00	500
27	Eighteen-inch vitrified pipe	1 500 Lin. ft.	2.50	3 750	2.00	3 000	5.00	7 500	2.50	3 750	2.50	3 750	6.00	9 000	4.00	6 000
28	Portland cement	35 000 Barrels	3.00	105 000	4.00	140 000	4.00	140 000	3.45	120 750	3.80	133 000	4.15	145 250	4.80	168 000
29	Screened gravel or broken stone	20 000 Cu. yd.	2.50	50 000	2.50	50 000	3.00	60 000	5.00	100 000	2.50	50 000	2.75	55 000	3.05	61 000
30	Gravel surfacing for roads	1 000 Cu. yd.	2.50	2 500	3.00	3 000	3.00	3 000	4.00	4 000	3.00	3 000	2.75	2 750	3.05	3 050
31	Bituminous surfacing for roads	20 000 Sq. yd.	1.00	20 000	1.50	30 000	2.00	40 000	1.40	28 000	2.50	50 000	4.00	80 000	1.77	35 400
32	Heavy riprap	35 000 Cu. yd.	1.50	52 500	1.00	35 000	3.00	105 000	2.50	87 500	2.50	87 500	3.50	122 500	10.25	358 750
33	Light riprap	50 000 Cu. yd.	1.50	75 000	1.00	50 000	2.00	100 000	2.50	125 000	2.25	112 500	4.40	220 000	3.05	152 500
34	Paving and dry masonry	1 000 Cu. yd.	6.50	6 500	3.00	3 000	10.00	10 000	7.00	7 000	7.00	7 000	5.00	5 000	5.40	5 400
35	Stone walls	7 000 Lin. ft.	2.50	17 500	2.00	14 000	3.00	21 000	2.20	15 400	3.50	24 500	3.50	24 500	6.10	42 700
36	Drilling holes in rock and masonry	10 000 Lin. ft.	0.70	7 000	0.50	5 000	1.00	10 000	1.25	12 500	1.75	17 500	1.20	12 000	3.20	32 000
37	Steel for reinforcing concrete	150 000 Pounds	0.06	9 000	0.08	12 000	0.07	10 500	0.075	11 250	0.10	15 000	0.07	10 500	0.07	10 500
38	Cast iron grooves	70 000 Pounds	0.06	4 200	0.07	4 900	0.12	8 400	0.12	8 400	0.11	7 700	0.12	8 400	0.09	6 300
39	Miscellaneous steel and iron	100 000 Pounds	0.08	8 000	0.12	12 000	0.10	10 000	0.16	16 000	0.10	10 000	0.16	16 000	0.17	17 000
40	Galvanizing	10 000 Pounds	0.02	200	0.10	1 000	0.15	1 500	0.10	1 000	0.05	500	0.10	1 000	0.22	2 200
41	Caring for and setting cast iron pipe furn. by City	300 Tons	40.00	12 000	20.00	6 000	50.00	15 000	50.00	15 000	40.00	12 000	15.00	4 500	70.00	21 000
42	Caring for and setting metal-work other than above	100 Tons	60.00	6 000	40.00	40 000	50.00	5 000	50.00	5 000	35.00	3 500	25.00	2 500	82.00	8 200
43	Timber and lumber	10 M ft. B.M	120.00	1 200	150.00	1 500	150.00	1 500	100.00	1 000	125.00	1 250	200.00	2 000	70.00	700
44	Wooden guard rails	5 000 Lin. ft.	0.60	3 000	1.00	5 000	1.00	5 000	0.60	3 000	0.65	3 250	1.00	5 000	0.70	3 500
45	Waterproofing	300 Sq. yd	1.00	300	2.00	600	3.00	900	2.00	600	5.00	1 500	6.00	1 800	2.75	825
46	Stream control and closure of conduit	Lump sum	.	5 000	.	15 000		10 000		10 000	.	10 000		62 500		13 650
47	Cleaning up	Lump sum	...	5 000	....	5 000		25 000		5 000		5 000		20 000		6 875
	Totals		......	$3 499 925	......	$4 487 425	..	$4 754 300	.	$4 903 112	....	$5 483 925		$6 084 550		$6 205 992

*Awarded May 4, 1921. Notice to begin work dated May 23.

TABLE 2. — CONTRACT DATA.

Contract.	Description.	Contractor.	Bids Opened.	Date of Cont.	Final Estimate.	Date Completed.
1	Wash and core borings on sites of Dam and Aqueduct in the Town of Scituate and the City of Cranston	Sprague and Henwood, Inc., Scranton, Penn.	Dec. 22, 1915	Dec. 27, 1915	$13 082.22	Sept. 20, 1916
2	Continuation of Contract 1	Sprague and Henwood, Inc., Scranton, Penn.	....	Sept. 20, 1916	5 333.69	Jan. 25, 1917
3	Stream control works for Main Dam including concrete conduit and earth approach channel	E. W. Foley Contracting Corp., New York City, N. Y.	Jan. 3, 1917	Jan. 11, 1917	113 798.85	Dec. 23, 1918
4	1.8 miles of gravel road from Plainfield Pike to Bald Hill Road (Portion of New East Road)	E. W. Foley Contracting Corp., New York City, N. Y.	Apr. 9, 1919	Apr. 14, 1919	53 009.31	Oct. 8, 1919
5	3.1 miles of gravel road south of Tunk Hill Road (Portion of New West Road)	Cenedella and Co., Milford, Mass.	May 12, 1920	May 14, 1920	156 788.72	July 7, 1921
6	1.75 miles of gravel road from Plainfield Pike to Rockland-Richmond Road (Portion of New West Road)	Louis Longhi and Bro., Inc., Torrington, Conn.	June 22, 1921	July 1, 1921	55 939.67	Dec. 7, 1921
7	3.4 miles of gravel road from Clayville to Plainfield Pike (Portion of Relocated Plainfield Pike)	The Sperry Eng. Co., New Haven, Conn.,	Apr. 9, 1919	Apr. 15, 1919	89 609.89	Dec. 23, 1920
8	Construction of the Main Dam and Dike and subsidiary works at Kent	Winston and Co., Inc., Kingston, N. Y.	Apr. 27, 1921	May 12, 1921	*3 199 925.00	....
9	Regulating Dam and Reservoir at North Scituate	E. W. Foley Contracting Corp., New York City, N. Y.	Aug. 21, 1918	Aug. 27, 1918	50 591.06	Dec. 20, 1918
10	3.5 miles of gravel road from Danielson Pike to Plainfield Pike (Portion of New East Road)	Linberg and Street, Boston, Mass.	Apr. 23, 1919	May 5, 1919	66 018.09	June 7, 1920
11	Completion of stream control works, approach and discharge channels and a portion of the Main Dam	The Sperry Eng. Co., New Haven, Conn.	Apr. 23, 1919	Apr. 29, 1919	164 031.72	Nov. 1, 1920
12	New outlet works at Moswansicut Pond and other incidental work, at North Scituate	George T. Seabury, Inc., Providence, R. I.	Sept. 17, 1919	Sept. 17, 1919	9 969.31	Dec. 31, 1919
13	Moswansicut River Bridge on the Danielson Pike at North Scituate	Thomas F. McGovern, Southbridge, Mass.	Sept. 15, 1920	Sept. 28, 1920	47 968.26	May 31, 1921
14	Surfacing with bituminous macadam 3.4 miles of road graded under contract 7 (Relocated Plainfield Pike)	Perini and Sons, Inc., Ashland, Mass.	Nov. 17, 1920	Nov. 17, 1920	100 858.46	Nov. 9, 1921
15	Grading & Surfacing 1.75 mi. of bituminous macadam road from Danielson Pike to Rockland (N. Scituate-R'land Rd.)	John Bristow, Narragansett Pier, R. I.	Oct. 5, 1921	Oct. 11, 1921	*258 617.50	....
16	For moving the "King House" for use as the Dam and Aqueduct Division Office	Sweeney Bros., Inc., East Providence, R. I.	Aug. 3, 1921	Aug. 9, 1921	1 200.00	Oct. 1, 1921
17	Alterations and repairs to the "King House"	Souther Construction Co., Providence, R. I.	Oct. 5, 1921	Oct. 11, 1921	3 735.00	Dec. 31, 1921
18	Plumbing and heating the "King House"	Thomas I. Hudson, Providence, R. I.	Oct. 26, 1921	Oct. 29, 1921	1 679.50	Dec. 21, 1921
19	Electric Installation at the "King House"	W. A. Huse and Son, Providence, R. I.	Nov. 9, 1921	Nov. 16, 1921	610.00	Jan. 5, 1922
20	Plumbing and Heating "Powell" and "Yeaw" Houses at Kent	F. G. Lees and Son, Providence, R. I.	May 10, 1922	May 15, 1922	1 014.00	June 5, 1922
21	3.3 miles of Scituate Aqueduct (tunnel) in the Town of Scituate and the City of Cranston	Keystone State Construction Co. Philadelphia, Pa.	Aug. 30, 1922	Sept. 20, 1922	*1 318 310.00	

* Basis of award, contract being uncompleted

about 54 000 g.d., the quantity varying directly with the percolation rate of the material used. It is seen therefore that the core material used is exceptionally well fitted for the purpose.

This paper of necessity cannot cover some interesting features of the project which are as yet in the formative stage and it may at some future time be desirable to present to this Association some further description of designs, of methods of construction, of bases of settlements for river diversion damages, now nearing a conclusion by negotiation, and of the experiences in the early years of operation.

A statement of contracts entered into to date, and a tabulation of bids on Contract 8 for the Main Dam and Dike are appended hereto.

The new water supply is being built by a commission known as the Water Supply Board, the members of which are B. Thomas Potter, Chairman, William A Schofield, Henry A. Grimwood, William P. Vaughn, John Kelso, Joseph H. Gainer, and Walter F. Slade. Samuel N. Grammont is Secretary of the Board and the writer is Chief Engineer; William W. Peabody, Frank E. Waterman and Francis B. Marsh, all members of this Association, are respectively Deputy Chief Engineer (in charge also of Dam and Aqueduct Division), Division Engineer (in charge of Reservoir Division) and Designing Engineer. Frederick P. Stearns and Samuel M. Gray were Consulting Engineers up to the time of their deaths, the former in December, 1919, and the latter in November, 1921. Messrs. Allen Hazen and J. Waldo Smith are on the present consulting staff. The writer acknowledges his indebtedness to all of the above mentioned associates and also to many others of the engineering staff, past and present. The valued advice and assistance of Charles T. Main, Consulting Engineer in mill damage cases and of Julius W. Bugbee, City Chemist, are also hereby acknowledged.

CO-ÖPERATION OF WATER WORKS OPERATORS WITH THE PUBLIC AND EMPLOYEES.

BY F. T. KEMBLE.*

[*September 13, 1922.*]

Following the drought season of 1910 and 1911 there seemed to be an awaking of the interest of the public in the matter of their water supply, with a good sized percentage of them in one way or another getting some posting, more or less accurate, perhaps sometime entirely erroneous, as to where their supply came from and some of the conditions of their service.

Formerly a great mass of people seemed to think that water should be free as air, but that, owing to the Municipality or some man or men having obtained the rights to serve in their territory, a tax was imposed on them. The sound shore district of New York State is a residential section with a population of as high average intelligence as elsewhere; yet numbers of them do not seem to be able to get away from the idea that we tax them and grade the tax according to the size of a house and the number of persons we believe occupy it, using our meters in some way that they do not understand to back up our arguments.

Some of you may recall the late Mayor Gaynor, a few years ago, writing an open letter to the Commissioner of Water Supply of New York City in which he expressed an opinion to the effect that the public should be encouraged to use as much water as they could in their dwellings, that it would be unwise to install meters in the tenements or houses of the poorer persons as they would be apt to use less water for bathing or culinary purposes, certainly they should not be charged by meter and that their tax should be as low as possible.

A certain percentage of those who take issue with us in relation to the amount of their charge, insufficient volume or something else, are really just "trying it on;" hoping that they will be slick enough to somehow or other come out ahead, but probably a majority of those who take up such matters with us don't at all clearly understand the situation. Many are convinced that they are right, that we are in error.

To satisfy our customers when they demand a lowering of their charges or a change in some of our conditions often times requires a lot of patience (if possible a customer should never be just gotten rid of), but the particularly annoying, hard customer to deal with is the party

* Secretary New Rochelle Water Co., New Rochelle, N. Y.

wanting to have pipes extended into the property he is developing; and in almost every case when such a party rows with us, it is a matter of "trying it on," endeavoring to get better conditions than others have.

In my opinion, doing business in as straightforward a manner as possible will later mean the most good to all concerned, — be far more advantageous than having gotten the best of matters at any particular corner.

When one has a set course of procedure, based on years of experience, some of the kicks and demands made seem hard to take seriously. Yet the ones who make them are to remain as customers; and, unless they are very outrageous, it is advisable to try to convince them that the company wishes to satisfy them, wishes to give them the best service possible under the conditions that obtain.

An endeavor to place oneself in the other fellow's position, to find his viewpoint, may be at any time of considerable service,— if in nothing else, in aiding one to disabuse him of some of the prejudice he generally comes in with.

The same idea might be suggested as regards dealings with one's employees, who — be they good, bad or indifferent — are apt to get a deal of ill advice off the job. This applies both to the Italians who at the meetings of their societies on Sunday afternoons, in addition to the listening to newspapers and yarns from back home in Napoli or Calabria, are from time to time harangued by countrymen of theirs who visit in from near by cities; and applies also to the men of more training and value to the plant who have relatives or friends, holding down political or other cinch jobs, who preach to them.

In my opinion what is particularly wanted from employees is "heart in the work;" and the more thorough the understanding between the heads of the force and the various members of same the better the chance for finding this.

I grew up in the service of one of the railroads particularly known for the *esprit de corps* and belongedness-to-the-job of its force. On the line we used to say that intelligence counted and experience counted but what counted most was heart-in-the-work; and my idea of the latter is that it should mean not merely zeal to get on the job but the continuous earnest effort to appreciate and further the requirements of a plant; and I consider efforts made by the force to make satisfied patrons of consumers as a showing that they have the interest of the plant at heart.

We are told a great deal about the inefficiency of men at work, of all classes. "They don't seem to care. We never were so poorly served. They are too old, etc."

Well, I don't know where we ever got 100%, and I'm sure that no matter what the cost or how many gray hairs may be put in the head of the men getting the work done, our plants are growing and we are accomplishing more each year than in "them good old days we hear tell on."

The old type of foreman that would bawl out his men proved not to be the one who could get best results from Dagoes who had been in the Army and had learned to jolly and tease and who were not to be handled the way their fathers had been; and yet some of these younger ones, though only too ready to sit around and look at work going on, can be led to take an interest in their work, to show what pep they've in 'em and so liven up a whole gang.

With both customers and employees, it is up to the Water Company management to get the work through that they are responsible for and the more heart put into their dealings the more thorough will be the accomplishment.

Discussion.

President Barbour This paper of Mr. Kemble's must have touched on some phases of water-works management which will appeal to some of you. It is different from the average paper, and I think it justifies discussion. Mr. Taylor is going to tell you how he organized the gang that we saw yesterday, and deny that they were speeded up for our particular benefit, as some of us were inclined to think.

Mr. Stephen H. Taylor * That was our regular organization. We have been laying pipe along those lines since July, 1921, and they are pretty well trained. They do that right along when there is trench open to lay the pipe in. There is not always so much trench ahead, but we made an effort to have plenty of trench ready. I think we put in about five while you were there during the half or three-quarters of an hour. That pace can be maintained as long as there is a trench ready. The digging is in rock and hardpan. The program is that the shovel goes ahead and excavates the trench, and the derrick follows behind and lays the pipe in it. As a matter of fact, the derrick lays, in two or three hours in the afternoon, what the shovel digs in a day. The material is loaded into trucks as excavated by the shovel, then hauled and dumped in the back fill. They excavate, lay and back fill anywhere from 75 to 100 ft. every day, with a crew of 12 or 15 men, two machines and a couple of trucks. I think we laid in one day 14 pipes, which was our maximum for one day, excavating, laying and back filling. Work which you saw was not particularly speeded up, except to have a little more trench open, perhaps, than usual.

In some cases, in going through the swamp, we had to go a little slower. It was very soft ground. The banks would cave in, and we would just dig out 12 ft., lay a pipe, and then in digging for the next pipe bring the shovel back and drop the material, taken out in front, into the back fill. The combination proved a very efficient way of handling the job. We have been through some wet swamp and have not had to sheet pile.

* Superintendent Water Works, New Bedford, Mass.

The derrick is also used for a pile-driver. The steam hammer which hangs on the derrick drives the piles. We put on the cap, pick up the pipe, put it in place, go ahead and drive the next pile, and so on.

PRESIDENT BARBOUR. Mr. Taylor, you did not catch my idea exactly. I was not so interested in the detail of what was accomplished as in how you established the morale which apparently was in evidence yesterday.

MR. TAYLOR. It is the result of the training of a year and a half on that same line of work, and the men who are doing that work have been with us for a great many years, and will do anything that we want them to do.

MR. BEEKMAN C. LITTLE.* I wonder if there is any solution of the difficulty that I have, and I think that all must have, of getting younger men to do the digging in the trench and the back filling, the work with pick and shovel. We have a very good lot of men but they are all getting older. They have been with us a good while and are loyal, and are the kind of men Mr. Kemble suggests. We have a great deal of coöperation from them. But have hard work getting new men to come in.

This question was asked the other day by somebody who came to the shop: "Ain't you got no automobile for me to drive?" I said, "No, we ain't got no automobile." They all seem to want either to drive a car or go into an office. There is a great deal of difficulty in getting men to do hard work. We can get men but they are not trustworthy.

MR. CALEB M. SAVILLE.† We have had in Hartford, some difficulty there, as elsewhere, because of minimum wages for new men but there are younger men that can be obtained.

I am rather inclined to think that the pension system for the older men may offer some solution of this problem. We have, as all of our New England Water Works Departments have, older men who have been in the department a long time. They know the business from A to Z; they know it a great deal better than many other people that can come in and do ordinary work. Those men are exceedingly valuable to us. And more than being valuable in knowing how, they will stay when the younger men, or the newer men, will not. If there is a wet trench, or something breaks in the middle of the night alongside the car tracks, which has to be fixed, those men will stay by and do the work. But they are getting older, and while they can spurt and do more work in a short time than some of the younger men will do, yet for steady, all around work, you have got to have the younger man with his younger muscles.

Now, the older men have gradually been increased in pay as wages have gone up, and many of them have come to the time when they are getting the maximum pay. When you take the younger man, whom you are going to rely on for muscle work, you can't put those men on at first

---

* Superintendent Water Works, Rochester N. Y.
† Chief Engineer Water Commission, Hartford, Conn.

at the maximum pay, you have to put them on at what you might call your minimum pay. Then you get into trouble right away, because the man who is getting the minimum wage, doing the strong arm work, sees these older men getting quite a bit more money than he is getting, and while he has some enthusiasm in the first place, and would be satisfied if the pay was uniform, it is the pay envelope at the end of the week that counts and makes him dissatisfied with his job.

So that there is something else which must offer a solution to your problem. If there was some pension system that the older men could look forward to it would be a good thing. Not a system that makes a man work forever before he can get a pension, but a system that gives a good, faithful employee really something to look forward to. I believe that something of that kind is bound to come in order to work out this problem, and I believe that in order to be most efficient the pension system must not be a gratuity for old age — charity if you please — but an insurance built up by payments from both the employer and the employees. In this way you approach the desirable ends; loyalty to service is created by personal interest in growth of the personal fund, and an investment available when the time of maximum abilities for service has passed.

Mr. J. M. Diven.* Some superintendents who manage municipal plants do not always have the choice of the men they will hire. If the superintendent gets out with his men once in awhile, gets down into the trench to see what is going on, makes himself more or less one of them, he may get better coöperation. I believe the superintendent who can't get the good will and loyalty, and even a little of the love of the man he works with, is going to make a failure.

Mr. Patrick Gear.† I do not know that Mr. Saville is familiar with the pension system we have here in Massachusetts. I know of a man who has been seventeen years a laborer, and has been a foreman now for two years, and when he is sixty-five he can retire at $400 a year as a foreman. If he had stayed a laborer he would retire at half pay, which would give him about $800 a year.

Mr. Saville. I said a good pension.

Mr. Gear. Now, it is more advantageous for a man to stay as a laborer than to go on as a foreman to-day. Then if he goes from that on up to be superintendent he doesn't get anything. The laborer has the advantage if he only knew it. Then you get the young class of men that Mr. Kemble speaks of, who are of the sporting type, and they are not reliable.

Mr. Henry V. Macksey.‡ I cannot agree that we wouldma terially help our present difficulty by the pension system. The cause of the trouble is that most of the young men whom we might expect to become laborers are American born, and educated. They are filled with an ambition to

* Secretary American Water Works Association.
† Superintendent Water Works, Holyoke, Mass.
‡ Superintendent of Public Works, Framingham, Mass.

be something better than laborers. We should be in sympathy with them. When a young man comes to me, an American born citizen, and wants a job as a laborer, unless he is in hard luck and really needs work and money at once, I try to find out what other line he is fitted for and to help him to properly place himself, rather than retain him as a laborer. I think that I am doing the right thing, for that man will never be a good laborer because his heart can not be in his work.

We all know that we have depended for years for crude labor on importations. The Irishmen of former days were the best laborers in the world; we can get no more of them, and our best bet is the Italian. The Italian is not yet assimilated. He does not think he is one of us. He does not take the interest in municipal affairs that the Irishman does.

Now, the real difficulty, it seems to me, is this: we do not have all year around work for all of our men. If we have a pension system we must keep the men regularly employed. With water supply work in this climate, of course we expect to carry a much larger gang in the summer than in the winter. In the winter our work is principally emergency work. The average city or town is not willing to do outdoor work in the winter, which costs 25 or 30 per cent. more than it would if done in the summer, just to keep an organization together. You can't keep a complete organization all the year round under our present way of managing municipal works. In our little town to-day we pay five cents per hour more than contractors are paying around us, but men do not come to us for work. The story told all over this part of the country to-day is that there is no idle labor.

Mr. Saville. I think I shall have to take exception to what my friend has just said. We have little idle labor in Hartford, and we can get all the labor that we need at reasonable prices.

We keep a rather large force all the year around in order to have an efficient gang. We have large forestry areas and they work in these during the winter. This increases somewhat in the summer.

Mr. Kemble. I have made a big effort in recent years to keep the men we have and get such men as we could. I have not been quite as altruistic as my friend, about men being better fitted for something else. I have tried to find work for them, wet or dry, and we have worked our gangs right through the winter. In bad weather we have tried to find work around the yards. The older men who are on the job will stay. They would be unhappy elsewhere. The younger Italians come and go. They won't stay with you as soon as they can get more money elsewhere, but will leave you in the lurch.

Mr. Richard H. Ellis.* It seems to me that in the small municipal system, a great many times we should meet conditions as existing in our neighboring industries. In other words, it is a case altogether of supply and demand. A good many times the municipality sets a wage over which the official in charge of the work has no option in granting a little more

* Superintendent Board of Public Works, North Andover, Mass.

money or a little less money, and consquently we have to put up with the type of labor that is willing to accept a low wage. The solution seems to be to pay a little bit more money, where we cannot hold our employees the year around, so as to get the best labor available. The pay envelope if it is large enough is sufficient incentive to get a man's best efforts.

Mr. Henry T. Gidley.* We have tried to make a practice of keeping a small gang employed most of the year round rather than a very large gang, but of course have more in the summer, but try to spread the work out throughout the year. We are a private company.

In the matter of pay, we confer with the Street Department to find out what they are going to pay, and pay about the same wage, so that the men are not dissatisfied and moving from one department to another. I think that idea of a small gang and keeping them employed, if you can do so, is rather better than to have a large force in the summer and discharging them all in the winter.

Mr. George F. Merrill.† I think Mr. Taylor's work is a good example of what the use of machinery will do in keeping the size of your gang down. I have found that in laying pipe with a trenching machine you can do with ten or a dozen men as much as could ordinarily be done with 40 or 50 under usual methods of hand labor. It gives a chance to employ a smaller gang, which can be kept employed throughout the year. And it keeps a better class of men.

Mr. Taylor. One of the main reasons we got the shovel was because of that big job of 36-in. pipe (about 6 600 ft.), on the boulevard, and there was a shortage of labor at that time. So we got the shovel to overcome that difficulty, but found it such a labor saver that we kept on with it when men were plenty.

Last winter when the ground froze up so that it was rather expensive to do that work, we put the crew in the woods on forestry work. Those who have forest work to do can utilize their regular gang in the winter, and that is the time of year when you can burn up your rubbish and do a lot of trimming and cutting out of dead wood. We keep practically all that gang the year around, besides other men down town for service work, and the emergency crew. I think our pay-rolls in the winter carry perhaps 40 or 50 of what might be called the laboring force, between the forestry work and the emergency crew. We also utilize our emergency crew in the winter in making up gate boxes, concrete forms, and all sorts of things for the next year's work. Our crew does not vary so much except when we get a big rush of small main pipe work, short lines, where it does not pay to send a shovel. When we get a rush of that we have to increase our crew.

In New Bedford the Portuguese prove about as good laborers as we can get, — better than the Italians. They seem to have a little more intelligence and more ambition to get ahead.

* Superintendent Water Works, Fairhaven, Mass.

† Superintendent Water Works, Greenfield, Mass.

DESCRIPTION OF NEW BEDFORD WATER SYSTEM.

BY STEPHEN H. TAYLOR.*

[September 12, 1922.]

On March 6, 1860, an order was passed by the City Council, calling for a committee "to consider the practicability and expediency of introducing a permanent supply of fresh water into the City and report some plan with the probable cost of doing so," etc. As a result of the studies of this and successive committees, an act authorizing the supplying of the City of New Bedford with pure water, was passed by the State Legislature April 18, 1863, and after three years' of study the first real effective water system in New Bedford was started in 1866. It was completed in 1869. A dam was built across the valley of the Acushnet River in the Town of Acushnet seven miles north of the center of the city. This created an impounding reservoir of 300 acres, at 40 ft. elevation above M. H. W., supplied by a water shed of about three to four thousand acres.

From this reservoir an egg-shaped brick conduit 4 ft. high by 3 ft. wide was constructed to bring the water to a receiving reservoir of three million gallons capacity, at an elevation of 30 ft., located in what was then the outskirts of the city. From here the water was pumped 1 879 ft. west through a 16-in. cast-iron force main to the Mt. Pleasant distributing reservoir, the capacity of which is fifteen million gallons, at elevation 154 ft., thence by gravity to the distributing system.

The original pumping engine was a five million gallon McAlpine, cross compound, of the walking beam type. This was later augmented by a three million gallon Worthington, and still later by a five million gallon Worthington, with the necessary boilers in each instance.

The population of the city was then about 20 000, and the distributing system consisted of 17 miles of main — some cast-iron but mostly wrought iron, cement lined, from 4 to 12 in. in diameter; and 553 services mostly of lead. The average consumption of water for the first year was 329 375 gal. per day.

In 1886 the consumption had increased to an average of 3 000 000 gal. per day. As this was beyond the safe capacity of the original impounding reservoir, a connection was made to Little Quittacas Pond by means of an open ditch $1\frac{1}{2}$ miles long, following in part an existing stream.

In 1893, 5 000 000 gal. per day was being used. That was about the safe limit of the system, and besides this, building activities were extending into the higher parts of the city, some of which were above the level of the reservoir.

*Superintendent Water Works, New Bedford, Mass.

Messrs. George S. Rice and George E. Evans, Engineers, were employed to make a thorough study of the situation and recommend the best means of obtaining an increased supply at greater pressure. Their work was done in conjunction with Mr. R. C. P. Coggeshall, Superintendent, and as a result of their combined efforts the present system was built. It has been in service since 1899, with the old Acushnet System held in reserve, the old distributing reservoir being connected by a check valve.

The right was obtained from the Legislature to take water from Little and Great Quittacas Ponds, located in Rochester, Lakeville and Middleboro, about twelve miles north of the city, with ample powers to construct and maintain the system. It also authorized acquiring such lands as were necessary for this purpose by purchase or condemnation.

A dam was built between Great Quittacas and Pocksha Ponds with suitable waterways for the discharge or overflow of the surplus waters from Great Quittacas into Pocksha, but preventing water from flowing back from Pocksha to Great Quittacas Pond.

A six foot masonry conduit connects Great and Little Quittacas Ponds, the flow through which is regulated by a sluice gate.

The storage capacity of Great Quittacas Pond is 4 500 000 000 gal.; the area of the pond is $1\frac{3}{4}$ sq. mi., and its water shed is $9\frac{2}{3}$ sq. mi. Little Quittacas has a storage capacity of 1 000 000 000 gal.; area of pond is about $\frac{1}{2}$ sq. mi. and water shed a little less than 1 sq. mi. The elevation of these ponds is 50 ft. above sea level.

No filtration or chemical treatment has been found necessary, as the entire shore of both ponds and a part of their tributaries is owned by the city. There are very few buildings on these shores. They are kept free from pollution and almost entirely covered with a good growth of wood.

It is a very gratifying fact that although all cases of typhoid or other water borne diseases are carefully traced, none has ever been traced to the city's water supply.

The city now owns about 2 000 acres of land on the water shed and is buying more as the opportunity offers. A great deal of forestry work has been and is being carried on there. Most of the hard woods have been cut off and many thousand white, red and Scotch pines have been planted, as well as some firs and hemlocks.

A scheme is now under consideration which, if carried out, will place the remaining Lakeville Ponds in the control of a joint commission for the use of all the cities and towns of Southeastern Massachusetts.

The combined area of the entire group of ponds is about 9 sq. mi., and the total water shed 38 sq. mi.

The pumping station is located on the southerly shore of Little Quittacas Pond. The pump well in the pumping station is connected by a six foot masonry intake, on the outer end of which is an eight mesh revolving screen.

The pumping equipment consists of two ten-million-gallon, steam driven, compound beam and fly wheel engines, designed by E. D. Leavitt and built by the Dickson Manufacturing Co. of Scranton, Pa., each operating two differential plunger pumps.

Steam is furnished by two 150 h. p. boilers of the Scotch Marine type, also designed by Mr. Leavitt. No extensive repairs have ever been necessary on this plant. It is still in excellent condition and is running twenty-four hours a day, showing an average duty of 130 000 000 ft. lbs. figured on total fuel used for all purposes.

A six million gallon DeLaval centrifugal pump driven by a G. E. squirrel cage, type I, 3 phase, 60 cycle, 550 volt, 250 h.p. induction A. C. motor was installed in 1918. This is a convenient auxiliary though less economical than the steam pumps, and can be operated without any additional attendants.

The water is pumped through a steel force main eight miles long to High Hill Reservoir. This pipe was laid across country in a strip of land 5 rds. wide, which was purchased by the City. From Braley's Station, on the N.Y.N.H. & H. R.R. to the Pumping Station, it is paralleled by a standard gage railroad. The road was built early in the construction of the system and was a very important feature in the transportation of the materials for building and equipping the Pumping Station and force main. It is used now for the transportation of coal and heavy supplies to the Pumping Station. All of the 6 600 tons of pipe for the new 48-in. cast-iron force main were delivered over this road. The main is of $\frac{5}{16}$-in. riveted steel with lap joints and coated inside and out with asphalt.

Great care was taken when laying it to patch the coating where broken in transit or in laying. Frequent tests for leakage are made and careful internal inspections have been made from time to time. Last year a piece was cut out for the purpose of making a 36-in. connection to the new 48-in. cast-iron now being laid. This piece may be seen at the Water Works Office in the Municipal Building.

The results of all these examinations seem to show that while there is considerable pitting, the pipe is still good for several years service.

A new 48-in. cast-iron main is now being laid which will make it possible to pump directly to the distributing system, in case of trouble with the steel main, using the reservoir as a balance. This cast-iron main will eventually be carried to High Hill Reservoir; we hope, before the steel main fails.

A wrought iron standpipe 20 ft. diameter by 75 ft. high has been erected and is connected with the new pumping main at the summit, which is also the highest point in the city. The connection to the main was made by using a tangent branch with the outlet arm at the top of the pipe. This is intended principally for an air vent and surge tank. The reservoir pressure fills the standpipe about half way, the remainder of the height allowing for the surge when pumping directly to the city.

High Hill Reservoir is located five miles northwest of the center of the city, in the Town of Dartmouth. When full the water stands at elevation 216 giving from 14 to 90 lb. pressure on the system. The average pressure in the business district and where the hotel is located is 65 lb. The reservoir is 1 000 ft. x 500 ft. x 20 ft. deep, and is divided by a masonry wall across the middle into two sections 500 ft. square. Its total capacity is 68 000 000 gal. The inlet and outlet gate houses are so arranged that either half may be emptied for cleaning or repairs and the other half kept in service. The piping is so arranged that the reservoir may be by-passed and water pumped directly into the distributing mains if desired.

The reservoir was built by excavating part of the top of the hill and building up the embankment in layers with a stone retaining wall from elevation 207 to 218; elevation 216 being H.W. The bottom and sides from elevation 196 to 11 are covered with a 9-in. layer of concrete. They have a slope of 2 to 1. The top of the bank is at elevation 220, and the outside slope is 2 to 1, and is covered with a good growth of grass from which quite a crop of hay is harvested each year. No leakage from the reservoir has ever occurred and aside from occasionally pointing up the stone walls at the water level, and a few very small cracks in the concrete slopes, no repairs have been necessary.

Two 36-in. cast-iron mains run parallel to each other from the High Hill Reservoir to the northwest part of the city from which point they form a loop of 36-in. and 30-in. pipe around the city. The entire distributing system is gridironed with a goodly percentage of large pipes as will be seen by the following statement of sizes:

48-in.	5.1 per cent.	36-in.	6.9 per cent.	30-in.	4.2 per cent.
24-in.	1 per cent.	20-in.	1.2 per cent.	16-in.	5 per cent.
12-in.	5.6 per cent.	10-in.	7.6 per cent.	8-in.	21.4 per cent.
6-in.	37.6 per cent.	4-in.	4.4 per cent.		

This does not include the 12 000 ft. of 48-in. cast-iron pipe being laid this year.

We are quite proud of the fact that this system is charged with only thirty-one of the possible seventeen hundred points of defect in the latest report of the National Board of Fire Underwriters. Fifteen of these are because of the pressure in the high value mercantile district being sixty-five instead of their standard eighty pounds. New Bedford is now in the second class in the National Board schedule of ratings.

Our mileage of main pipe, 4-in. and over, at the beginning of the year was $185\frac{3}{4}$ not including hydrant branches and blow-off connections. The system is cut into moderate sized sections by 2 515 gates. There are 1 650 public and 447 private fire hydrants. The number of services is 16 354, all the active ones being metered except private fire supplies.

Water is also supplied to the towns of Dartmouth and Acushnet

through meters located at the Town Line, as well as a few houses in Freetown and Lakeville.

The average daily consumption last year was about 9 500 000 gal. or 71 gal. per capita. Manufacturing meters account for 41 per cent., domestic and commercial meters for 40 per cent., leaving 19 per cent. for fires, flushing and all unmetered uses and leakage.

Water is sold for manufacturing purposes at 10c. per thousand gallons and for all other purposes at 15c. per thousand. Public buildings, parks and cemeteries are charged the same as private owners, but no income is derived from fire hydrants or private fire supplies. The annual revenue of the department is sufficient to cover all maintenance and repairs including payment of bonds, sinking fund and interest, and provides for a moderate expenditure for extensions each year.

The total cost of the works to December 1, 1921, was $4 676 910.93, and the net debt was $482 755.97. Both figures are exclusive of the $700 000 bond issue for the new 48-in. cast-iron force main now under construction.

Since the beginning of the works the total receipts for water have been $7 273 084.85 of which $1 826 662.79 have been applied to construction. All ordinary extensions including the 48-in. main now under construction are made by the department.

In 1920 the department had about 6 600 ft. 36-in. main to lay in addition to the ordinary extensions, and as labor was scarce, it was decided to purchase a 14B Bucyrus Steam Shovel with an extended dipper arm for trenching, and in 1921 when the 48-in. main was started a 14B Bucyrus "Clamshell" and derrick machine with a 30-ft. boom was purchased. These machines have proved great money savers on the large pipe work which has been done in the past three years. The latter machine is used for pipe laying, and in places where the ground is too soft to support the steam shovel over the trench, excavating is done with the clamshell outfit on the same machine. Under ordinary conditions the excavation is done by the steam shovel travelling on platforms over the trench with the derrick following close behind, laying the pipe. The shovel deposits the excavated material into trucks which haul it directly to the backfill close behind, or to the spoil bank.

With reasonably good conditions, from 120 to 180 ft. of trenching, pipe-laying and backfilling per day is accomplished with a crew of from 15 to 20 men, two or three trucks, and the steam shovel and derrick. The advantage of a small crew is particularly great in our present work, which is ten to twelve miles from the city, and as there is very little local labor available the men must either be boarded near, or transported to and from the job.

A convenient and well equipped work shop and pipe yard are maintained near the center of the city, with an emergency crew and gate operating truck always available to handle breaks or other sudden calls.

Experiments with Substitutes for Lead for Jointing Cast-Iron Pipe.

Until within a comparatively few years Water Works engineers have been pretty unanimously of the opinion that the best if not the only satisfactory material for jointing cast-iron bell and spigot pipe was a good grade of soft pig lead, well caulked. As you all know, it was applied by pouring the melted lead and then driving it firmly into the joints with caulking tools.

During the past fifteen or twenty years various substitutes have been placed on the market and widely advertised throughout the Water Works field. The principle advantages claimed for these substitutes was the great saving of expense for both material and labor.

The writer, like all good conservative Water Works officials, has hesitated to change from the established custom of using lead.

Some ten years ago a few joints in the smaller sized pipe were made in the New Bedford Water system with two of the substitutes,— Leadite and Lead-Hydro-Tite, and no trouble has ever been experienced from either.

In the Spring of 1920, the writer decided to make some more extensive experiments with them. The City of New Bedford was then contemplating the laying of about 6 600 ft. of 36-in. pipe in addition to the usual yearly work, and as prices of everything were extremely high, any saving that could be made without decreasing the efficiency of the work was worth considering.

At that time Leadite was offered at 12c. per pound and Lead-Hydro-Tite at 10c. while lead was selling for about $7\frac{1}{2}$c. per pound. One pound of either substitute would fill as much joint space as four pounds of lead, so that it would take 30c. worth of lead to do the same work as 10c. worth of Hydro-Tite or 12c. worth of Leadite. There is also a further saving in the reduced labor cost, because no caulking is necessary, and the size of bell holes is greatly reduced. The only chance for skepticism, then, was as to their efficiency. As the contemplated work involved a considerable amount of jointing material, the two cents per pound difference in cost of Leadite and Hydro-Tite, was worth saving if the two materials were equally efficient. The experiments here described were made to determine this point as well as to determine their ability to stand high pressure, and the elasticity of the materials.

The experiments were made with the assistance of Mr. W. R. Conard, Engineer, Mr. Hays R. Kuhn, at that time employed by the Pennsylvania Water Co., who was familiar with handling Leadite, and Mr. Jacob Handy, Superintendent of Dartmouth Water Works, who had considerable experience with Lead-Hydro-Tite. Mr. George McKay of the Leadite Company and several Water Works officials from nearby cities and towns were also present.

Experiment No. 1. Six lengths of 6-in. pipe were put together on skids about two feet high in the pipe yard of the New Bedford Water Works, with a plug and sleeve on one end made up with lead and a patented plug in the other. Three joints were made of Leadite and three of Hydro-Tite. Dry white jute was used in their different forms. One joint with each material being made with loose yarn, one with the same yarn twisted lightly, and a third with the same yarn braided; similar in appearance to packing, but without oil or grease.

The pipes were first filled at city pressure (84 lb.) and the joints were all reasonably tight, the greatest leak occurring at the joint made of Leadite with loose yarn.

There were also some leak at the joint made of Hydro-Tite with twisted yarn. The pressure was then raised, first to 150 lb. and then to 200 lb., all joints remaining reasonably tight and becoming entirely so with the exception of the two above mentioned. The high pressure was then released and normal yard pressure (84 lb.) maintained during the remainder of the test.

The ends of the pipe were raised by means of a derrick at each end, the supports, which were under the pipe, being removed as the pipes were lifted from them until, for a short time, the line was practically suspended by the ends, forming a curve with about 144 ft. radius and the ends 5 ft. 9 in. higher than the center.

Finally joint No. 5 of Hydro-Tite broke, allowing the center of the line to drop to the ground. It should be said, in fairness, that the joint which failed was not made with a continuous pouring, because some of the material was lost through a defective dam and a second pouring was necessary. Only a few seconds elapsed between the first and second pouring, however, as the kettle was close to the joint and it was only necessary to dip out more material.

The whole line was then lowered to the ground and remained tight except the two joints before mentioned (No. 2 and No. 5). These were made tight by caulking with a little lead wool, and for several months the line remained in the yard in asbolutely tight condition, in spite of the abuse to which it had been subjected.

Experiment No. 2. As the principal work of the year was to be 36-in. pipe, it was thought advisable to experiment with this larger size to see if it could be successfully poured. Two lengths of 36-in. pipe were joined, with a plug in one bell and a sleeve and plug on the spigot end. Accidentally a class B pipe N.E.W.W. Assoc. specifications was placed into a class F bell. This made an unduly thick joint (about $\frac{7}{8}$-in.). The class B bell was too small to receive the beaded end of the plug, so the plug was reversed. This made an abnormally thin joint with no bead, as the space was so small that it would have been impossible to caulk a lead joint. These joints were made with Leadite. On the other end the sleeve and plug were normal $\frac{1}{2}$-in. joints and poured with lead Hydro-Tite.

When the yard pressure was applied, in spite of the bracing at the ends, the joint between the two pipes slipped about $\frac{3}{4}$-in. This was the abnormally thick joint. The 84 lb. yard pressure on the 36-in. plugs develop a total stress on each of them of about $42\frac{1}{2}$ tons.

The braces were then removed and the pressure applied with the intention of pulling the work apart. When this was done the two abnormal joints made with Leadite held fast, and the one where the sleeve joined the pipe which was a normal $\frac{1}{2}$-in. joint made with Hydro-Tite pulled apart.

As a result of these tests, it was decided to adopt Leadite for our work, and it has been used in practically all the joints made since that time with excellent results.

The story of this test would not be complete without further reference to the advantage of the braided jute packing, which we have also adopted for general use. We find that although it costs a little over twice as much per pound as the plain dry jute, the saving effected in labor and material more than offset the extra cost, and that a better joint is obtained because there are no loose ends of the fiber to mix with the jointing material and reduce its efficiency.

Since writing the above, a very favorable opportunity was presented for comparing the cost of 48-in. joints made of lead and Leadite, as two joints were made of lead on the check valves of our 48-in. line, because of the extreme weight of the casting and uncertainty of the ground in which it was placed.

Figuring the cost of jute packing, labor and lead, a 48-in. joint cost \$18.06; whereas the same items on Leadite joint cost an average of \$4.42. It took three men one hour and forty minutes to pour and caulk a lead joint, whereas the same three men would average to pour from six to eight joints per hour with Leadite.

Discussion.

Mr. William W. Brush.* How long was your high service reservoir in use before you cleaned it? If I recall correctly, you said you had 6 in. of deposit.

Mr. Taylor. There was about 6 in. of deposit. That was the result of about fourteen years of service since it had been cleaned. It was very light material.

Mr. Brush. In what way does that deposit cause you any difficulty?

Mr. Taylor. It did not cause us any difficulty, but thought as a matter of protection and cleanliness we had better clean it out.

Mr. Brush. Did you find any difference after you had cleaned it in the quality of the water over what it had been before you cleaned it?

* Deputy Chief Engineer Bureau of Water Supply, New York.

Mr. Taylor. I would not say there was very much difference. Our outlet is raised up a little from the bottom so that it did not get that sediment. I suppose there would come a time when the sediment would get to the bottom of the outlet and then it would be drawn into the mains.

Mr. Brush. There was no difference in the microscopic growth, or anything of that kind?

Mr. Taylor. No. I should say it was a vegetable deposit. The water, of course, travelled across the reservoir, and in the earlier days it travelled much more slowly, because the capacity of the reservoir is 68 million gal., and when the reservoir was built our consumption was 5 000 000 a day, so that the rate across was slow and it had lots of time to settle. Now it goes across faster because our rate of consumption has doubled. We use now 10 000 000 or 10 500 000 gal. a day.

Mr. J. M. Diven.* What trees do you plant on your watershed, Mr. Taylor?

Mr. Taylor. We have planted mostly pines, starting with the white pine, supposing they had about as few enemies as any other tree. Then came the white pine borer. We are now planting, as fast as we can get them, red and Scotch pine. We have not yet found the enemies of the red pine and Scotch pine and are using them at present, although it is very difficult to get enough of them. Last year I had to take about half of the white pine and the other half red and Scotch.

Mr. Diven. In New York they have given up the white pine entirely.

Mr. Taylor. It is only within a few years we have had trouble with the white pine. We are cutting off the hardwoods as fast as possible on account of the gypsy moth. I would like to find a tree somewhere that has no enemy to destroy it; I have taken up the question with our State Forestry Department and gotten the best advice available.

A Member. What age pine do you plant?

Mr. Taylor. We have raised some from our own seeds, but usually get about three or four year transplants. We sometimes transplant a large section from our own reservation from one place to another. When buying we buy three and four year seedlings.

Mr. Diven. How are you taxed on your property outside of the city?

Mr. Taylor. That was fixed by the Legislature in our Act of 1914. The average valuation for the three years previous to the time we bought it becomes a fixed valuation for all time. Valuation can be neither raised nor lowered. Of course the assessments rise and fall with the tax rate, but the valuation remains the average of the three previous years.

Mr. Diven. They do not tax you on your improvements?

Mr. Taylor. No.

Mr. Diven. You get out better than we do in New York.

Mr. Taylor. They get us a little bit outside of our watershed. We have two houses for our engineers to live in, and they tax us there to make up on what they lose on the watershed.

---

*Secretary American Water Works Association

MR. DIVEN. Are you taxed the full cost value of the pipe lines in the ground?

MR. DIVEN. No; we pay the city on the same valuation made for the three previous years, without any tax on the mains.

MR. DIVEN. That is a fair and equitable tax.

MR. TAYLOR. I think so. Where we go through a town we sometimes furnish them with water. In Freetown, where our new main is laid, if they want water we serve them at the same price that we do in New Bedford. That, of course, benefits the town a little.

MR. GEORGE W. BATCHELDER.* Did you have to get special legislation to furnish water in Freetown?

MR. TAYLOR. Yes. And it is the same in any other town. It is the same with Dartmouth and Acushnet.

MR. J. A. RAINVILLE.† Is there anyone here who has had experience with cement pipe?

MR. TAYLOR. Our experience with it is of old times. When the system was first built, I should say perhaps more than half of it was cement lined pipe, but it got pretty weak and before we put on the increased pressure due to our new system we got it all out and replaced it with cast-iron. Several breaks occurred in it from time to time. I think other cities are using it more sucessfully.

MR. FREDERIC I. WINSLOW.‡ How much trouble did you have in getting your men to use Leadite properly?

MR. TAYLOR. None at all. We had a man come here who had been familiar with using it a number of years. We put a green man on who was a fairly intelligent laborer, and after seeing one or two joints made he did it himself. There was no difficulty in instructing a man of the ordinary laborer's intelligence. Of course you would not take the greenest sort of man, but one of your ordinary laborers can learn to use it in a short time.

MR. BRUSH. Do you use Leadite here in the city?

MR. TAYLOR. Yes; we are using Leadite almost entirely. As the result of our test we felt that for our particular purposes Leadite was what we wanted. It seemed to hold up, in my opinion, a little stronger than the other. I think, as a matter of fact, for ordinary light work, there would not be a great deal of difference between the two. But the test we made seemed to show to me, and all who were present at the test, that the Leadite was a little stronger for all around work.

MR. BRUSH. Have you had any mains break where you have used the Leadite?

MR. TAYLOR. No. We have not had the slightest trouble from any cause. I do not know of a joint that we have even had to dig up, and we have put in, in the last few years, about ten miles in our regular distributing system, and about three and a half or four miles in our large 36

* Water Commissioner, Worcester, Mass.
† Foreman Crystal Water Co., Danielson, Conn.
‡ Division Engineer Metropolitan District Commission.

and 48-in. mains. There are very few joints in New Bedford which have been tested before turning the water on. We were so confident that the pipes are now covered before filling. Once in awhile we have uncovered a joint, thinking it a joint leak, but it proved to be surface water, or something else. So that our experience with Leadite has been very satisfactory.

Mr. A. O. Doane.* I think it would be interesting if you would explain the difference in the jute, as you did this morning.

Mr. Taylor. Either one of these joint materials requires white, clean jute. We are using a braided jute. There is a sample of it in Mr. McKay's exhibit. It costs about double the cost of unbraided, per pound; but it saves, I think, more than that in labor and wastage. There is no wastage from the braided jute, which is cut just the right length, and braided good and hard. A man tamps it in all around, and you do not have to drive it with a hammer. There also is an advantage in a joint of that sort in not having any loose ends running out to destroy the joint. We feel, even thought we pay twice as much for it, that better results are obtained by using the braided jute. It is the same grade of dry jute as the unbraided.

Mr. A. B. Coulters.† What pressure was maintained on the pipe in your yard during the flexure test?

Mr. Taylor. Eighty-four pounds. I might say, we had a caulker who was some caulker, and that after the joints broke down he drove some lead wool into the broken joint, and the line lay in the open yard for months, absolutely tight with the pressure on.

Mr. Frank A. Marston.‡ In the northern part of New York State, there are a number of miles of 6 and 8-in. pipe, in a system for a spring water supply, which were laid with Leadite, and it was found by test that the leakage from Leadite joints was not much greater than from lead joints, after letting the joints stand for about a week. At first the joints would drip a little and at that time would fail to pass the test limiting the allowable leakage to two gallons per linear foot of pipe joint for twenty-four hours, but after standing for a few days, or a week, the leakage would be reduced to acceptable limits unless there was an imperfectly formed joint.

One section of pipe which was laid in about a 6-ft. trench was exposed during the middle of the day to the sun, while during the remainder of the day it was shaded. In the morning and at night the joint would be tight, but in the middle of the day when the sun rose so that it shone on the pipe and warmed it up there would be enough expansion so that the joint would begin to drip a little.

As far as laborers are concerned, my observation has been that it is just as well to start with a green man rather than to take an experienced

* Division Engineer Metropolitan District Commission.
† Of Builders Iron Foundry, Providence, R. I.
‡ Of Metcalf & Eddy, Boston, Mass.

lead melter, to avoid prejudiced ideas as to how the compound should be melted. The jointing operations are very simple, and an intelligent laborer can readily learn to make good joints after a few days instructions.

Our experience has shown these two compounds, Leadite and Lead-Hydro-Tite, to be satisfactory where the conditions permit of their use.

MR. FRANKLIN HENSHAW.* The difficulty we had with one man, who had previously been an expert in handling lead, was his insistence on making a low gate, and you cannot get a good Leadite joint unless the gate is amply high. Another difficulty was with the jute packing. Where the braided jute was used we did not have a bit of trouble, but in one case they ran out of that and tried to make a joint with unbraided jute, and did not get the fibres on that jute all packed into the back of the bell, a few would stick out, and in every case where that happened there would be a drip. It would be found in the course of time, but it made a great deal of trouble at first. Consequently, the braided jute was ordered and used entirely after that.

MR. HENRY T. GIDLEY.† I would like to say that we have used almost entirely for three years the Lead-Hydro-Tite with very good success.

I think some of the former speakers were right when they said that they do not want to take a man who has melted lead to use on the Hydro-Tite, for the Lead-Hydro-Tite does not require so great heat as the lead, and they are apt to burn it up at first, because you can get it too hot easier than you can just the right temperature.

The bending qualities of Lead-Hydro-Tite we have tested where we had to lower our pipe, and in one case we lowered 72 ft. of 6-in. pipe 2 ft. with the water pressure on and no leaky joints. In another case, where the grade was changed in a street, where there was a cross street and we had to lower the pipe, we lowered it 2 ft. in 100, and the cross T was lowered a foot, and beyond the cross T the pipe was lowered until it started to buckle a little, but no joint in the pipe showed the least sign of leaking. This was over a little rise, so that the pipe as lowered was really shortened rather than lengthened.

MR. TAYLOR. I may call your attention, Mr. President, to the last sentence of this little paper of mine, — "Figuring the cost of jute packing, labor and lead." There was an opportunity to make a pretty accurate comparison. We made two joints on a very heavy check valve, which was in a soft bottom, with lead, with the idea it might need to be recaulked at some time or another. The average of those two lead joints was $18.06. That is simply the packing, labor and lead. While the same items in the Leadite joint cost an average of $4.42 per joint. That makes no allowance for the very great difference in the depth in digging and maintaining bell holes in wet trenches.

MR. W. C. HAWLEY.‡ We have recently completed a line of 8-in. pipe, but on account of delay in getting a right of way we had an oppor-

* Superintendent Water Works, Scarsdale, N. Y.
† Suprintendent Water Works, Fairhaven, Mass.
‡ Chief Engineer and Manager Pennsylvania Water Co.

tunity to test about a mile of it before it was put into service. After a day or two we found that the leakage was so little that it would not register on the best $\frac{5}{8}$-in. meter that we could pick out. I do not know just what that is in cubic feet per hour, but you can see that the leakage was very small.

We usually test our pipes in the open trench. Perhaps it is not necessary, but we believe that it gives us a little closer check on the man who is making the joints, because if we find a joint that shows any considerable leakage, anything more than mere seepage, we know there is something wrong in the way that joint was poured, and it gives us an immediate check on the man who poured it.

I want to take this opportunity, by the way, to correct a statement that was made in the last JOURNAL, to the effect that I was the first one to use Leadite in Atlantic City. That is not correct. Mr. Kenneth Allen, my successor, used Leadite there, I think in 1903 or 1904. I did not use it until a year or two later at Wilkinsburg.

PRESIDENT BARBOUR. Mr. Marston, I believe you referred to the use of Leadite in a suction system from springs. Does that mean it was under a vacuum suction system?

MR. MARSTON. No; it was a gravity system.

PRESIDENT BARBOUR. Has anyone ever used Leadite where the pipe was under a partial vacuum? (No response.)

MR. PATRICK GEAR.* I would like to know if any of those gentlemen who use Leadite would take a chance under a railroad track, where you have to cover it up before testing.

MR. TAYLOR. We would be perfectly satisfied to go ahead and use Leadite. We always cover our pipe as soon as laid, without waiting for a test, we are so confident of it. We never yet have had a failure, and sometimes it is under quite a strain.

MR. HAWLEY. If the pipe is laid by a man who knows how to lay it, that is the place for Leadite.

MR. MARSTON. In a pumping station where pipe is subject to vibration, Leadite has been used up to 12-in. pipe, and they have stood up very nicely.

PRESIDENT BARBOUR. I think I am stating the fact in saying that Mr. McInnes has used Leadite in the crossing over the Neponset bridge where there is very pronounced vibration, and has used it in preference to lead at that point.

MR. ALEXANDER ORR.† Has anyone used Leadite or other substitutes for lead in any of the exceptionally cold cities where we have to do considerable thawing by electricity?

MR. GEORGE MCKAY, JR.‡ Mr. Bugbee of Trenton, N. J., in the very cold winter of 1917, had 2 000 services frozen, and used electricity

* Superintendent Water Works, Holyoke, Mass.
† Superintendent Water Works, Gloversville, N. Y.
‡ Of the Leadite Co.

in thawing. They never had any difficulty in putting the current through. I think the main thing is to keep the voltage low and get the amperage up to about 250. Do not get the voltage too high.

Mr. Orr. Are those laid in the regular manner?

Mr. McKay. Laid in the regular manner.

Mr. Doane. Is there testimony to be offered as to the effect of electrolysis on the water pipes containing these compounds?

Mr. Hawley. I can say that the Leadite materially decreases the amount of current flowing through our mains.

Mr. Brush. From your experience would you consider there would be any serious difficulty in running water mains where your mains would be laid by a contractor who received a contract as a result of being a low bidder, where there would be no testing of the mains although the contractor would be held responsible for a year for any leakage that developed?

Mr. Taylor. If I was having work done by contract I should certainly want to see it under pressure before it was covered. We do all of our own work here, that is why we cover it up. We have men who are very familiar with it, and we feel confident. But if it is going to be done by contract I would want to see it under pressure before it was covered, by all means.

Mr. Diven. I might add one thing to that, Mr. Taylor, and say, whether it is going to be done by contract or not.

Mr. Joseph A. Hoy.* In making water-works caps, do you use Leadite, or lead?

Mr. Taylor. We usually use Leadite. When we had a big cross connection, a 36-in. or a 48-in. steel main, we put the responsibility up to the Water Works Equipment Company. They made the joints with lead, and filled in the space between the joints with cement grout. But we have used Leadite in many cases, and with good success, on our own work.

Mr. Diven. I would state for the information of the gentleman that I made, on a 30-in., with the water on, a Leadite joint for two 8-in. outlets, tapping the sleeve through two 8-in. outlets. I had absolutely no trouble.

Mr. Taylor. We very seldom contract any work that we can do ourselves. The 48-in. job is handled very comfortably with the present outfit. I had estimates made of the cost of steel and cast-iron mains for that job, getting a contractor's figure for 48-in. main, and using our own estimate of our own cost of laying a 48-in. cast-iron main and comparing it with the contractor's figure for a 48-in. steel main.

We could, by doing the work ourselves, put in the cast-iron main for about the cost of a steel main through contract, and the difference in value is considerable, or, at least, that is my opinion. You get a 48-in. cast-iron main by doing the work yourself for the price of a steel main by contract.

*Foreman Water Dept., Worcester, Mass.

PRESIDENT BARBOUR. I think that is a most remarkable statement that Mr. Taylor has just made. I think you had better add, if you can, the price of cast-iron at the time the comparison was made.

MR. TAYLOR. At the time cast-iron was high. My estimate was based on $70 per ton. Steel was also high, of course. I should think the difference between steel and cast-iron was less now than it was twenty-three years ago when the old system was laid. At that time there was considerable difference, and it was figured that the interest on the difference in cost — both by contract, of course — in twenty years would re-lay the main, of course using the prices of that date as a basis.

But as a matter of fact we all know that the prices are very much higher now.

MR. BRUSH. Have you found any corrosion on the exterior of your steel line?

MR. TAYLOR. No. All interior, from tuberculation and pitting.

MR. BRUSH. Have you had any failure in the entire line?

MR. TAYLOR. No absolute failure.

MR. BRUSH. Have you estimated about how much longer that line will last? I know you stated that you were putting in cast-iron as a security against possible failure of the future.

MR. TAYLOR. Yes.

MR. BRUSH. You said that some of the pitting had gone through just under one-half the thickness of the metal.

MR. TAYLOR. About that. Very roughly we have estimated that we ought to get fifteen years more life out of the steel pipe. That is on what we have seen. Of course we do not know the condition in some places where we have not seen it. But we felt it was a much safer measure to have this second main in readiness if it did let go.

MR. DIVEN. That will make a total of thirty-five years?

MR. TAYLOR. Yes, if it runs fifteen years longer, thirty-eight years.

MR. DIVEN. What kind of soil is it laid in?

MR. TAYLOR. A little of everything; swamps, gravel, and some few clay spots.

MR. DIVEN. Any pitting in the clay?

MR. TAYLOR. I have not seen any piece from outside where there was any pitting. I perhaps ought to say that we have not uncovered very much.

MR. DIVEN. My experience is just exactly the opposite. Especially in clay soil there is more pitting from the outside than the inside.

MR. TAYLOR. We make frequent tests for leakage in that steel main by the weir chamber, shutting off all outlets and noting the drop in the very small weir chamber, and it has been very tight every time it has been tested. We are not guessing, but know it by actual test.

A NEW METHOD OF PURIFYING WATER.

BY H. W. CLARK.*

[*September 14, 1922.*]

Probably the chief objection to slow sand filtration in the minds of many sanitary engineers and water-works officials is that this method of water treatment seldom removes from the comparatively clear but often highly colored waters of the eastern states more than from 25 to 30 per cent. of this color, and hence does not produce a filtrate as clear, sparkling, low colored and altogether attractive as the filtrate from coagulation and rapid filtration of such waters. On the other hand, perhaps the chief objections to the method of coagulation and rapid filtration when applied to these soft, highly colored waters, are; the tendency of this method to increase the corrosive properties of the soft water treated, the difficulty with which, as generally speaking, equally good bacterial results can be obtained, as by slow sand filtration, especially if these soft waters are badly polluted; and the fact now again being widely commented upon that occasionally aluminum sulphate does pass through such filters.

Owing to these objections or criticisms of the two methods, a process of water treatment that will produce a sparkling water of low color without materially increasing its corrosive properties, has been much desired and such a method I believe we have worked out at the Lawrence Experiment Station of the Massachusetts Department of Public Health. I am calling this a new method although we have been experimenting with it since the latter part of 1916 and have published in our reports short summaries of the results obtained.

Briefly, the process consists of loading the sand of a slow sand filter with the ordinary coagulants used in mechanical filtration and operating such a filter generally at slightly more than the usual slow sand filter rates or about 5 000 000 or 6 000 000 gal. per acre daily. Filters loaded in this way remove a very large percentage of the organic matter, especially the coloring matter of the applied water, produce an effluent clear, sparkling and altogether attractive, containing no more carbonic acid than in the raw water applied to the filters and with the carbonate constituents of the water slightly increased.

This method of water treatment has many advantages over each of the other methods and but one drawback. The advantages are as follows: (1) The corrosive properties of the effluent are not increased or if so, not materially, and neither aluminum sulphate nor alumina is found in the filter effluent; (2) the aluminum hydroxide with which the filter is first loaded is regenerated whenever its color removal properties begin to

*Chief Chemist, Massachusetts Department of Public Health.

fail and hence is used over and over again, — that is, the primary cost of coagulants is practically the final cost; (3) when receiving comparatively highly colored water from storage reservoirs practically free from mineral matter in suspension, such as silt, etc., the method of filter regeneration or removal of stored color which we employ, removes practically all organic matter from the surface of the filter as well as from its deeper portions and hence the necessity for scraping the filter is largely obviated, — that is, the expense of sand removal and sand washing is reduced to a minimum. Filters of this type now in operation at the Experiment Station have been scraped only once or twice during a period of five years' operation at rates of 5 000 000 gal. per acre daily; (4) there is, as I have already stated, practically no consumption of alum. Filters operated now for five years have theoretically used up to date, taking into consideration the amount of aluminum sulphate primarily placed in the filter and the volume of water filtered, about .2 of a grain of sulphate per gal. of water filtered or practically one-twelfth of the amount necessary per gallon in sucessful mechanical filtration of the Merrimack River water such as applied to these loaded filters. As the loaded filter increases in age and the volume of water filtered and decolorized increases, the theoretical or apparent use of alum grows less and less per gallon. Successful mechanical filtration of Merrimack River water costs in the neighborhood of $6 or $7 per million gal. for aluminum sulphate while with this new method the cost to date has been about 55 cents per million gal. for this sulphate, and this cost is constantly growing less: that is to say, if in the next five years we filter as large a volume of water as in the past five and without additional loading of the filter, the cost will be 28 cents per million gal.

Up to date we have operated eleven filters loaded with aluminum sulphate but for purposes of this paper the results of only five or six need be given. One filter, put into operation in January, 1917, and constructed of 4 ft. in depth of sand with an effective size of .25 mm., was loaded with 80 tons of aluminum sulphate per acre of filter surface. The aluminum hydroxide was precipitated in the sand by flooding the filter alternately with small doses of solutions of soda ash and sulphate, although the filter can be loaded by mixing an alkali such as magnesium carbonate with the dry sand and then applying solutions of the sulphate. During its five years of operation the average color of the effluent from this filter has been 14 and the color of the water applied to it, 41 — a removal of 66 per cent. During long periods the color of the effluent has averaged 7, however, and during portions of these periods the applied water has had a color of 60, 70 and even 75: that is, the filter has given an average color removal during such seriods of about 90 per cent. In other words, the line of the effluent has always been nearly straight while the color of the applied water has had many high peaks and the higher the color of the applied water the greater the percentage of the coloring matter removed. Up to date this filter has removed rather more than 50 per cent. of the

organic matter determined as albuminoid ammonia and 60 per cent. of that determined as oxygen consumed. It has been treated with weak solutions of caustic soda twenty-four times in five years in order to remove the coloring matter held in the filter by the aluminum hydroxide. After this treatment with caustic such a filter is washed with a volume of water equal to about 2.5 to 3 per cent. of that filtered between treatments and is then ready for service for a period of two or more months. It is not necessary to use filtered water for this washing out of caustic. The amount of caustic used up to date in the filter described has been .5 of a grain per gal. of water filtered, or, in other words, the expense for the caustic used has been about $2.50 per million gal. of filtrate. We believe, however, judging from later results that we have used in this particular filter an excessive amount of caustic and that this figure may be much reduced. A filter loaded with 150 tons of aluminum sulphate per acre has given an average color removal of 78 per cent. during the past two years when operated at a 5 000 000-gal. rate and a filter constructed of sand as fine as .11 mm. effective size and operated at a 2 500 000-gal. rate has produced an absolutely colorless effluent since first put into operation. The cost of efficiently loading an acre filter is a small percentage of the cost of filter construction.

The bacterial results from this method are poor as the caustic used removes from the sand grains much of the gelatinous organic matter so necessary for the retention of bacteria; but the effluent — clear, low in color and sparkling — is easily rendered practically sterile by the use of small amounts of chlorine, and chlorine is in almost universal use at filter plants at the present time in order that their effluents may be absolutely safe.

This method of treatment is particularly applicable to stored waters of a high color, the improvement of which physically is of more moment than the reduction of bacteria; and it has seemed to us that there is no serious objection to it which would prevent its use upon a large scale. Recent experience has shown that perhaps the better way of loading the sand would be to carry this loading process on in comparatively small tanks or bins and then transport the sand to the filter. By this method more even distribution of the hydroxide would be obtained and stratification prevented.

The following table illustrates some of the results obtained at the Experiment Station during the past five years:—

	Filter Number.					
	491.	512.	513.	511.	515.	516.
Tons of aluminum sulphate per acre precipitated in filter,	80	75	75	150	150	225
Color removal (per cent.),	66	73	73	73	78	76
Number of days between caustic treatments,	65	67	67	89	89	90
Grains of caustic soda used per gallon of water filtered,	.52	.21	.12	.16	.32	.16
Approximate percentage of wash water,	2.5	3.7	3.7	2.8	2.8	5.5

Rate of each filter 5 000 000 gal. per acre daily.

Discussion.

A Member. Does the aluminum hydrate come through the filter at all?

Mr. Clark. Not after you get the loading adjusted. When loading the filter you may not get your proportion of soda and sulphate just right to cause complete precipitation of hydroxide, but by testing the water coming through you can adjust that.

Mr. George W. Fuller.* I would like to ask whether during the period of some two months or so between regeneration of the hydroxide there is any diminishing percentage in the removal of color; in other words, is the greater the amount of aluminum hydrate you have available the greater the removal of color, so that during the first ten days after you regenerate you get a less of color?

Mr. Clark. Yes. When you are running a single filter, this filter removes all color at first from the water and then when the color of the effluent gets up to 14 or 15 we regenerate the filter. If you have a battery or series of filters, by regenerating each one separately the increase in the color of the effluent as the filters are used would not be noticeable; that is to say, the color of the mixed effluents could be kept at the desired point.

A Member. Is regeneration of the filters carried on by reversing the flow?

Mr. Clark. We flush the caustic over the surface.

Mr. Robert Spurr Weston.† When you regenerate with caustic soda, you of course reduce the amount of hydrate available for the decolorization?

Mr. Clark. We have not found any appreciable amount is taken in that way.

Mr. Weston. You do not, after regeneration, need any replacement of the original loading?

Mr. Clark. We have not replaced any in five years, and our filters are working just as well as they did five years ago, i.e., removing just as much color. We may be losing some slight amount of aluminum hydroxide from the filters but have never found any in the effluents.

A Member. One question occurs to me along that line. Some highly colored swampy waters that are decolorized require a large amount of aluminum hydrate to get as nearly colorless a water as you can obtain but this does not remove the salts or acids that cause taste. They may have been decolorized but apparently the swampy taste is not removed. Did you consider that at all?

Mr. Clark. We have not considered that but our effluents are practically tasteless. The Merrimac River water at times in the last two or three years, especially the last year, has been very highly colored.

*Consulting Sanitary Engineer, New York City.

†Consulting Engineer, Boston, Mass,

MR. FULLER. Of course economics of this problem would relate a good deal to the amount of turbidity, mineral turbidity or microscopic organisms like *Algae* in the applied water, and then your regeneration period would be controlled by other matters than the amount or organic matter held in the filter sand.

MR. CLARK. The regeneration period would not be changed. It would be necessary probably in such a case to scrape the filter just the same as it would if you did not have it loaded with aluminum hydroxide, as you would any sand filter receiving such water.

MR. J. M. DIVEN.* Then after scraping you would not have to recharge?

MR. CLARK. No.

MR. GILBERT H. PRATT.† Unfortunately I did not hear all of Mr. Clarke's paper and he may have covered the point I am about to inquire about. I am wondering whether in loading the bed this has been done by the aluminum sulphate — soda ash treatment to successive small layers of sand or to the bed after in place. If the latter, it would seem to me that there would be a heavy layer on the top of the bed and as I said before I am wondering if it was done by treating successive small layers.

MR. CLARK. I think by doing that you might perhaps, once in a while, get a stratified layer, a fine layer; that is, your aluminum hydroxide precipitate might be too heavy at one place in the filter. As I said in the paper, you can obviate that by having bins or tanks in which you charge or load your sand before placing in the filter.

MR. PRATT. My point was whether you thought you had a heavier layer on the top possibly?

MR. CLARK. We may have a heavier layer on top if the filter is not properly loaded but it is easy to load the filter correctly. I think one of the great things about this method is the low cost for aluminum sulphate. When you come down from $5 to $6 a million gallons to 55 cents and then keep on going down so that it is perhaps half of that before you have to use any more precipitant, you are making a great point on the economy side. I have more data on this subject but haven't it with me because I did not want to talk about things that I was not absolutely sure about.

MR. WESTON. Is there any material change in the pH value of the water?

MR. CLARK. Yes. The pH value of the water is increased. We are running a mechanical filter right beside these filters with the same water and the pH value of the effluents from our loaded filters is greater than the effluent of the mechanical filter.

MR. F. W. GREEN.‡ Can you see the aluminum hydroxide in the sand layers?

* Secretary American Water Works Association, New York City.

† New England Manager, Wallace & Tiernan Company, Newark, N. J.

‡ Superintendent Filtration & Pumping, Montclair Water Co., Little Falls, N. J.

MR. CLARK. It is very difficult to see it unless a portion of the filter is over-loaded.

MR. WELLINGTON DONALDSON.† May I ask Mr. Clark what strength of filter solution is used in filling or loading a filter?

MR. CLARK. Very weak solutions as very slow loading is required.

MR. M. N. BAKER.‡ In the paper it is stated that there are four or five advantages and one drawback and the drawback is not clearly pointed out anywhere in the paper. Perhaps the author of the paper would mention more specifically what the drawback is.

MR. CLARK. The drawback is the poor bacterial results. The process as we use it removes about 75 to 80 per cent. of the bacteria as determined by the 4-day 20°C. count and a larger percentage of *Coli* is removed but the bacterial efficiency of the filter is nothing like that obtained by good sand filtration or good mechanical filtration. As I have stated, the process is particularly applicable to the treatment of waters, the physical improvement of which is of more moment than bacterial improvement.

MR. GREEN. This most interesting paper of Mr. Clark's apparently shows the existence of certain physical-chemical properties of aluminum hydroxide of which we have no former record. These properties may account for the mutual precipitation which is brought about when a colored stream and a turbid stream are intermixed by Mother Nature.

When a solution of aluminum hydroxide is applied to a colored water the floc forms much more quickly than when a solution of sulphate of alumina of equivalent value reacts with the alkaline constituents of the same water. The decolorizing action of the more slowly formed floc is much greater than that produced when the floc is formed rapidily. It is possible to form a floc so rapidily that masses of considerable size are produced before there is a reaction with the organic coloring matter contained in the water. Only the surface of the individual particles is stained, the interior remaining white and thereby showing that it has not participated in the decolorizing action. Some recent experiments by the writer with a certain colloidal coagulant which is now being introduced on the market,* also show that it increased the reaction with the organic constituents if you retarded the formation of the floc.

In connection with cleaning sand by means of caustic soda, we have found by laboratory experiments that it is possible to remove all of the organic matter from the sand grains by this method. Also that a hot solution of the mixture of acaustic soda and soda ash gave the same results at a lesser cost.

It would be of interest to know if there is a coating of the alumina on the sand grains, or just what is the physical condition of the hydroxide.

† Chemist, Fuller & McClintock, New York City.

‡ Associate Editor, *Engineering News Record*, New York City.

* Sendel's Colloidal Coagulant. Seydel Chemical Co., 120 Broadway, N. Y.

Mr. Stephen DeM. Gage.* I have been very much interested in Mr. Clark's paper for the reason that, with one or two exceptions, our water purification problems in Rhode Island are concerned with color removal and improvement in physical quality, rather than with removal of pollution.

From the figures which Mr. Clark has presented it seems that this new process might have considerable value in particular cases even if experience shall show that it is not of broad application. The more processes we have to choose from, the more satisfactorily and economically we can work out our individual problems. In explaining the figures on the chart, Mr. Clark specifically mentioned a color removal of 66 per cent. with a filter containing 80 tons sulphate of alumina and an increased color removal with a filter containing 150 tons per acre. The chart also shows results with two other filters containing 75 tons per acre with a color removal of 73 per cent., or almost as great removal as the filter containing 150 tons. This might perhaps indicate that there was a certain definite load of alum needed to produce the best results, and that any material increase over that amount would not be worth while. I should like to ask Mr. Clark if he can give us any further information on this point.

Mr. Clark. I did not. We did get 73 per cent. removal with 75 tons of aluminum sulphate.

Mr. Gage. Is that related to the fineness of the sand?

Mr. Clark. The fineness of the sand in our filters was as nearly the same as we could have it.

* Chemist and Sanitary Engineer, Rhode Island State Board of Health.

THE USE AND DISCARD OF AUXILIARY FIRE PROTECTION FROM A POLLUTED SOURCE.

BY CALEB M. SAVILLE.*

[*September 13, 1922.*]

The matter of secondary fire protection by use of water from a polluted source, controlled by automatic check valves designed to close when the secondary supply is turned on, has been the subject of so much discussion within the past few years that it seems desirable to put on record some of the experiences that have been passed thru in Hartford, Conn.

The intent is to state the facts from the water works standpoint, and to complete some of the statements which have appeared from time to time in favor of such systems.

Hartford, Conn., the home of the largest fire insurance companies in the world, was the first to sanction the use of the so-called Double-Check Valve control between its public water supply system and a secondary source of water to be used for fire protection.

It is therefore of interest to note that after a trial period of 13 years, Hartford also has been the first city to discard such control and to require the complete severance of all connection between its water system and any other.

These connections joined city pipes, carrying carefully filtered water, with pipes into which might be forced water flowing in the Park River, which is dirty and foul with sewage and waste. Under certain combinations of circumstances this water would be injected into the pipes carrying water for domestic use.

History.

Historically and briefly stated, the fact that there were a number of emergency connections between the Park River and the City water mains only more or less controlled by check valves of the ordinary type, buried in the ground, was brought to the attention of the Water Board of the City of Hartford in August, 1907, by Mr. E. M. Peck, a member of this Association and Engineer of the Board at that time.

An order was issued by the Board soon after, directing discontinuance of the connections; but after several conferences with the manufacturing interests affected it was agreed to stay the execution of the order until trial could be made of a double-check valve combination which had been designed by the engineers of the Associated Factories Mutual Fire Insurance Company.

*Manager and Chief Engineer Board of Water Commissioners, Hartford, Conn.

These installations were completed by February, 1909, and their operation was described on page 239, vol. 30, JOURNAL N. E. W. W. A. (1916).

The matter did not come up again until July 1915, when the writer of this paper reported to the Water Board that "the valves very frequently are found not to close tightly, due to foreign matter being caught on the seat under the clapper." Owing to the very nature of the service a valve left absolutely tight by the inspector may be found leaking again soon after his visit, although he had left the valve perfectly tight.

For example, in 1921, and this is only one of several instances on record, although perhaps the most aggravated case, from January 20 to March 19, inclusive, because of failure to hold tight on test, the same valve was visited eight times, and each time found to leak on test, and each time put in order and left tight when tested.

The Associated Factory Mutual Inspector also made a test during this period, found the valve leaking, repaired it, as had the water-works inspector five days before, left it tight, and nine days later the water-works inspector again found it leaking.

The report of the inspector states each time that the valve seats were found dirty, and had to be scoured, and several times the rubber seat ring had to be changed around or renewed.

In most every case the emergency supply was taken from the excessively polluted Park River, a stream draining about 60 sq. mi. including thickly settled parts of the factory district of New Britain, the center portion of West Hartford, as well as the congested part of Hartford.

That there is a real danger in such connections is evidenced by the epidemics of typhoid fever traced to connections between the public water supply and polluted streams, as at Circleville, Ohio, February, 1914, Philadelphia, Pa., 1913, Springfield, Ohio, 1911, New Bedford, Mass., 1903 and others. The fact that there may have been no improved type of check or possibly only a gate valve on these does not weaken the evidence of potential danger in the connection, at most such installation could be only one more barrier and not a preventive.

December, 1915, this matter was again before the Board on recommendation to refuse thereafter permission to extend the system, and the recommendation was adopted although protested by the Engineer of the Factory Mutual Companies.

September, 1918, the matter of connections was again brought to attention, by the continued presence of *B.Coli* in the tap water at the laboratory, which is located near the center of the city.

An exhaustive search located the trouble in a large department store where there was an emergency connection between the city water supply and a secondary supply drawn from a well driven several hundred feet into the red sand stone formation underlying the city, and from which water was pumped into a tank on the roof of the building.

Controlling this connection were two check valves of the ordinary type.

This sandstone layer dips toward the east and is crossed by the Park River, from which the factories drew their secondary supply in case of need. There are many of these wells in Hartford being used to furnish cooling water for refrigerating plants. Many tests of the water from these wells have shown the presence of *B.Coli* in those east of the river, but none in those to the west. The assumption therefore seems warranted that there is direct connection by fault or seam between the river and the wells.

The connection causing the trouble was ordered removed forthwith, and on September 25, 1918, a special committee of the Water Board recommended that an order be issued for the disconnection and subsequent prohibition of all connections between the city water system and any other supply. This recommendation was approved by the full board, and the order issued, to be effective within a reasonable time after notice.

Believing their factory plants to be seriously menaced, the manufacturers affected, again ably supported by the engineers of the Associated Factory Mutual Insurance Cos., made a strong protest against the operation of the order; brought in an eminent sanitary specialist to give his opinion of the comparative danger from pollution or from fire; another engineer to give general testimony; and designed, and built at considerable expense a full sized model valve all of bronze, with rubber gaskets of specially prepared material, which they offered to install in the place of the "F.M." valves then in service, and which they and their specialist now frankly acknowledged to be unsatisfactory.

Through all of the controversy the manufacturers acted in the very best spirit, as good citizens, open-minded and anxious only to have that protection to which their plants as important to industrial well being of the city were entitled. Indeed, after the matter was finally disposed of, some of them said that they had been misled as to the adequacy of fire protection afforded by the city departments and if they had been previously as well informed they would not have opposed the order as they did. At one of the first meeting a prominent manufacturer said that the matter of cost did not enter in, the only consideration being proper protection, and subsequent actions fully bore out this assertion.

It is also pertinent to say that the all bronze valve designed by Mr. C. D. Rice, manager of the Underwood Typewriter Plant, is by far the best mechanism of its kind that has come to my knowledge, and the nearest substitute for actual severance of connections, although in my opinion there is a very wide chasm between no connection at all and one controlled even by the Rice valve.

However if you must have double-check valves insist that all bronze valves of the Rice type be furnished.

Thereafter several hearings were held by the Board at which interested parties appeared and submitted testimony concerning the necessity for

continuance of the connections for fire protection service and of the very remote chance of pollution of the city water.

At one of these meetings the present installations were roundly scored by one of the best known sanitary experts of the country, who appeared for the manufacturers to testify as to the very remote chance of pollution and the relative danger of considerable loss by fire and of loss of life by polluted water from these connections.

Even this specialist, however, stated that "there was some danger in any connection of the public water supply with a polluted source, and that as a general rule health officers and practical water-works operators are opposed to connections of this character; nevertheless, that he believed that such connections could be made of little danger if controlled by a properly designed check valve system; that the present design was not satisfactory, the chief difficulty being that there was a danger of binding of the hinge and of rust and pipe moss becoming lodged under the seats." He further suggested that "these difficulties could be largely overcome with the construction of a bronze valve differing somewhat from those at present in use." He would not admit, however, that even with such a valve there would be absolutely no danger, but stated that he did believe that with such a valve the danger of pollution could be so reduced that it would be of less importance than the dangers to life and property from insufficient fire protection.

On November 15, 1920 it was again voted to proceed with the disconnections.

Again, however, at the request of the manufacturers, who wished to submit additional testimony and to have consideration given to an all-bronze valve which they had had built and installed on a test connection, two other hearings were held, at which time, beside the manufacturers and their attorney, there were also present a representative of the Associated Factory Mutual Fire Insurance Company (Inspection Department) and a representative of a New York Engineering firm who had been retained by the remonstrants.

After this hearing the matter was finally closed by reaffirmation of the order to disconnect, with time extended to January 1, 1922, the last hearing having been held July 11, 1921, and the manufacturers at once proceeded to install other means to give service satisfactory to the fire insurance underwriters.

In all of this discussion nothing but the best of feeling prevailed between the manufacturers and the Water Board or its employees, and when the final decision was reached the manufacturers as a unit acted as good sports and good citizens; they accepted the verdict with good grace and without quibble went to work to carry out the spirit as well as the letter of the order.

As the hearings progressed the impression was given that the insurance interests most concerned were more disturbed on account of the general principle of disconnection than with its particular effect in Hartford.

It is noteworthy that none of the fire insurance stock companies made any objection to the elimination although, as stated, the principal offices of the larger companies are located in Hartford, and their engineering staffs were thoroughly informed

The manufacturers stated that it was not at all a question of expense to them in making the substitution, as their only concern was adequate fire protection, and that they had been led to believe that this could be afforded only by the double-check valve connections. This contention of the manufacturers was also clearly evident by their attitude and sincere effort to find some substitute which could be considered the equivalent of complete separation.

Notwithstanding this it is not known that there was any increase in insurance rates due to the change, and in one case it is stated that a considerable saving was effected by the rearrangement.

Leading up to the accomplishment of separation of the secondary supplies, so much study was given to the matter generally and to local conditions in particular that a résumé may be of help to water-works men in more readily getting some information which in many of its phases is of vital importance to those responsible for furnishing pure and safe water to consumers.

Auxiliary Connections Prohibited.

In order that absolute protection of their water supplies may be had, many cities absolutely prohibit connections between the city water supply and any other source. Among these are Springfield, Mass., Providence, R. I., Lowell, Mass., Philadelphia, Penn., St. Paul, Minn., Cleveland, Ohio, Stamford, Conn., and Terre Haute, Ind.

The Minnesota State Board of Health absolutely prohibits these connections and has ordered out existing ones; the State Board of Health of Illinois "sanctions no such physical union in the installation of new factory supplies."

Legal Responsibility to Supply Safe Water.

In reviewing the "Mankato Typhoid Case" where damages were claimed and paid for typhoid death and disease due to polluted water entering the city mains, the Supreme Court of Minnesota said;* "It is obvious, that a sound policy holds a city to a high degree of faithfulness in providing an adequate supply of pure water, nor does it appear why citizens should be deprived of the stimulating effects of the fear of liability on the energy and care of its officials; nor why a city should be exempt from liability while a private corporation under the same circumstances should be held responsible for its conduct and made to contribute to the innocent persons it may have damaged."

*Jour. A. W. W. A., Jan., 1920, page 47.

In denying the application for reargument, in the same case, the Court made the following statement: "The decision rested in effect upon this supreme consideration; namely, that public policy requires the conservation of human life, the preservation of the public health, and the establishment of public sanitation on a firm and certain basis in the law."

Secondary Supplies Desirable.

Secondary sources of water supply are desired because of the risk of one means of fire protection being inadequate or out of commission in the emergency, and fire insurance underwriters properly give somewhat lower rates to factory risks having such connections.

Methods For Obtaining Secondary Supply.

This secondary supply may be obtained in several approved ways; by use of elevated tanks, by use of large cisterns underground, or by connections with a stream. So far as is known, there is no difference in rate due to the use of any of these modes. In the two methods first mentioned city water may be used to fill tanks and act as a reserve, or polluted water may ordinarily be used with the city water entering above the highest point to which the impure water can reach. In the third case highly polluted water may be used separated from the domestic supply only by automatic check-valves.

Check-Valves Leak.

Check valves and gate valves of any and all kinds leak more or less at times and there can be no positive assurance that any of them are absolutely tight at all times. Record of test of double check-valves in Hartford during the past 10 years disclose 61 occasions on which leaky check valves have been reported. Of these, on 34 occasions there was leakage in the outer check, 21 occasions leakage in the inner check and 6 occasions leakage through both checks. In two cases of different sets, leakage through both sets was found on two successive monthly inspections although the valves were left tight on the first inspection. There is, however, no question that at any time a zealous employee may directly by-pass the double check in his endeavor to improve the factory water system without realization of the danger of pollution to city supply.

Park River Not Drinking Water Supply.

The Park River is badly polluted, and if its water finds a way into the city mains an epidemic of typhoid or similar disease is probable.

Typhoid Epidemic Due to Leaky Check Valve.

In 1903 a single check valve, said to be specially built and the best of its kind, failed in Lowell, Mass., when subjected to similar conditions to which the Hartford double checks would be subjected in case of fire; and the result was an epidemic of typhoid fever in which 9 persons lost their lives and 172 persons were incapacitated for a greater or less period due to illness. The financial loss in life and health in this community due to this epidemic can be estimated to have been in the vicinity of $100 000. The fact that in this instance there was a single check instead of a double one is of relative importance only.

Limited Use of Double Check-Valve System.

The double-check valve system in Hartford was used by eight of all the factories here located, the remainder using tanks of some kind for secondary supply when this is required.

Small Openings a Source of Danger.

A small crack under a check valve such as might be caused by a particle of rust, sand or other foreign body, or the sticking of the hinge due to corrosion, might prevent the clapper of the valve from seating and allow as much water to be forced through by a fire pump on a double check-valve as it is estimated was responsible for the trouble emanating from the auxiliary supply mentioned above.

Right of Board to Order Disconnection.

As to the right of the Board to prohibit the use of auxiliary connections and order disconnection of those now in use, it appears that the installations exist under what may be considered as a revocable license subject to order of the Board of Water Commissioners, who are responsible for protecting the purity of the water supply. The earlier leanings of the law toward granting precedence to property rights over rights of personal protection have gradually been changing, and at the present time it is generally recognized by the courts that protection of life and health is paramount to protection of personal property. In order to show just cause for order to discontinue any nuisance prejudicial to public health it is probable that the courts would hold it unnecessary to prove the actual occurrence of disease and death resulting therefrom, and would require only reasonable evidence that the continuance of the nuisance might produce conditions which would be detrimental to the welfare of the community.

Double-Check Device Best Protection of its Kind.

The double check device is probably the best of its kind if automatic connections must be had between a polluted source and the city water supply. That this device, however, is not perfect is indicated by the corroded condition of the interior of the present valves, the constant supervision to keep them in even approximately usable condition and the fact that the underwriters' design itself has been modified from time to time in the matter of seat rings, valve facings, distance of valves apart, and the necessity in at least one case of using an auxiliary weight on the clapper to make the valve seat tight. In order to give more assurance of tight closing under pressure it is now found necessary to insert a rubber gasket in the face of the valve. While the rubber is in good condition this makes a tighter joint than the previously ground face. On the other hand, when the rubber becomes worn or the life goes out it peels off, in places, and leaves a larger opening for water to go through.

Chance of Failure of Valves.

Absolute safety lies only in physical separation of these two services. With the character of inspection which has been given in the past, the chance of pollution with these check valves on fire protection connections only, must be recognized as probably remote. While such connections exist, however, the chance exists that at some time there will be failure, and conditions serious to life and health will obtain in the city water supply.

Double-Check Valve Systems Allowed by Public Bodies.

The statement is made that certain public bodies have allowed the use of this check valve in water systems. It appears from correspondence that this permission is not at all a general one, has been reluctantly given in special cases, and none of these bodies appear to consider this check valve an alternative for complete disconnection as a safeguard to public health. In most cases, where the device is allowed, there are many restrictions placed on the use, which is also limited as regards number of connections and character of the secondary supply. On the other hand, all of the Boards of Health state that absolute safety is obtained only with no connection with a polluted source and defend their action in allowing the check valves on the ground of policy and expediency. Many other cases can be cited where no automatic connection whatsoever is permitted between the public water supply and a secondary source.

Financial Loss from Epidemic Comparable with that of Fire.

The financial loss to the community in case of epidemic is fully as much as, if not greater than that in an exceptional fire.

Johnson states that the failure of a double-check valve to act properly at the right time is a greater menace to health than fire, and incidentally he

adds that in the United States in the past 30 years the vital capital dissipated by typhoid fever was over three times the net property loss from fire, "so in questions like this, offering a choice between the loss of life and the loss of property, there should be no hesitation in lining up on the side of health."

Opinion in Regard to Double-Check Valve Connections.

In connection with this matter, the opinion of Mr. Leonard Metcalf, one of the best informed engineers in the country on matters relating to municipal and sanitary work, may be of interest (*Proceedings Am. W. W. Assoc.*, 1912, p. 174) in his answer to Mr. J. Walter Ackerman, Supt. of Water Works, Auburn, N.Y., who asked what chance there would be for pollution in the case of the then recently installed double-check valves in that city. Mr. Metcalf said: "In regard to the desirability of using a double-check valve, this decision must be reached after very careful consideration of all the local conditions. Health should unquestionably be first taken into consideration. If you have a city supply used as a primary supply, not as a secondary supply, but as a primary supply, and a secondary supply which is reasonably safe, it would seem that there should be no question but that a double-check valve, with proper inspection at stated periods by water-works departments as well as by insurance agents, might be adequate, particularly in those cases where the pressure maintained on the risk side of the check valves is less than the pressure maintained in the city mains. *If you have, on the other hand, a secondary supply, or even a primary supply, taken from such a stream as Bubbly Creek*, undoubtedly you have no right to take the hazard of installing even a double-check valve system, because the dangers of injury to the public are altogether too great;* so that you must take into consideration in making your decisions, first, the question of the character of the primary supply and of the secondary supply, admitting always that it is desirable that the primary supply should come from the pure public supply; second, the relative pressure maintained on the two pipe systems; third, the character of inspection which you can be sure that you will get.

"As to the effect of corrosion on the double-check valves, it would seem that this is met by inspections. If you have periodic inspection, the inspectors must know what the condition of the valves is, but even in that case, if the secondary supply is much polluted, the speaker would not want to rely upon a double-check valve."

Where the line is between Bubbly Creek water and that which is absolutely safe, it is then a matter of individual judgment, and the part of the supply man is to play safe with human life, because if the one chance in a million of a typhoid bug getting by and causing an epidemic, does materialize, it will not be the insurance company engineer who will have the burden.

---

* A highly polluted stream in Chicago Stockyards.

Large Factory Fire Supplies a General Risk to the City.

The increased risk of fire damage and conflagration due to elimination of secondary supplies in a city as well safeguarded as Hartford in its public water system is as nothing compared with the risk put on the whole fire protection of the city by the sprinkler supply systems in the larger factories. A broken sprinkler main might so reduce the pressure in the city system as to put a much greater risk on the general fire hazard of the city than it is possible to place on the individual hazard of any factory by the elimination of the secondary supply.

Adequate Fire Protection Without Risk to City.

It is very truly stated in the letter of the manufacturers that "no practicable substitute supply can approach the equivalent of the protection now afforded by the public water supply through our sprinkler systems." It is, therefore, fair to presume that this advantage is reflected in the rates given to individual plant owners.

In the case, therefore, where a secondary supply is desired, and an adequate one may be obtained without suspicion of danger to the health of the city, even if some expense is put on the individual, little if any actual hardship is imposed in the view of the special gain enjoyed by the individual from use of the city system as a primary supply for the protection of his property. Moreover, if it is a hardship on the few to lose the source of secondary supply under consideration, this loss is measurable in dollars and cents; whereas if there is any loss of life due to the introduction of polluted water into the city mains, an irreparable hardship has been placed on the many, because life and health are not to be appraised adequately by any financial measure.

Private Fire Systems Mostly for Private Advantage.

As to public advantage derived from factory fire protection installation, special gain to plant owners from the benefit derived by them from a public water supply connection to sprinkler systems, has been too often recognized by the Courts in rate cases to warrant any successful argument to be made of a paramount advantage to the city in safeguarding life and property by such installations.

Importance of Manufacturing Industries Recognized.

The Water Department of the City of Hartford has fully recognized the importance of its manufacturing interests to the existence and prosperity of the city. The benefits accruing to the city from adequate private fire protection systems in safeguarding the lives of its citizens employed in factories and consequential damages resulting from spread of fire to other plants and the losses resulting from interruption of business has been carefully considered and generously met by this city department.

Advantageous Conditions.

For example, no charge is made for the large supply mains under high pressure, nor for the ready-to-serve feature of the city supply which allows of very large reductions in insurance rates to plant owners, a condition considered by the courts as a benefit not incidental but as a peculiar service provided in general. In many cities of importance, annual charges are made for connections of large size whether or not used, and often times a charge is also made for each sprinkler head installed. No charge is usually made for water used for extinguishing fires; but a meter is often installed on all fire lines in order to prevent surreptitious use of water and to allow of a charge being made for leakage and waste in factory systems. None of these methods have been pursued in Hartford.

Editorials in re Cross Connections.

Pertinent to this subject, excerpts from two editorials appearing in the Engineering press are of interest as showing the trend of public opinion. (See Appendix G.)

Fire and Water Engineering, January 21, 1920. "The Trend Toward Safer Water"—"If a city is responsible for the condition of its public highways and is liable in case of injury resulting from neglect of proper care, how much greater is the responsibility when the same neglect puts in jeopardy the health of an entire community."

Engineering New-Record, May 13, 1920. "Leaky Cross-Connection Kills Fifteen," commenting on the result of a leaky valve which admitted polluted water to the city mains.

"Unfortunately there are still some engineers, especially those in the employ of the fire insurance companies, who see no harm in cross-connections or who put property risk above life risk."

In view of the above facts and after careful consideration of the subject of dual connections existing between a public water supply system and a polluted source, here and elsewhere, the following recommendation is respectfully submitted:

Loss of Life by Fire.

In some of the cases the author has read, advocating the use of the "F.M." Double-Check Valve as a water safeguard, reference is made in several cases to the large loss of life in the burning building, and the inference drawn was that had there been double-check valves the regrettable condition would not have occured.

Most of these references have been looked up, replies were received from a majority of them and in every case the answer was that the loss of life was due neither to lack of water nor of fire fighting apparatus but to inadequate means of exit or to flimsy building construction.

State Sanitary Engineers Conference.

At the conference held at Boston, Mass., June 1, 1921, the matter of cross-connections was taken up and thoroughly discussed. As the accounts of the conclusions of that body have been somewhat misleading because of partial quotations, it is desired to state here the main principles of that valuable report and it is hoped that the whole body of conclusions may be included in an appendix.

Principle No. 1. No cross-connection should be established or maintained between the public water supply system and any other water supply system, private or public, unless both water supplies are of safe sanitary quality and both supplies have received the approval of the State Health Department.

Principle No. 2. In cases where it is necessary or advisable to supplement an impure private water supply with the public water supply, distributed in the same piping system, the public supply must be made available by delivering it into a cistern, suction well or elevated tank at an elevation above the high water line of such cistern, suction well or tank.

Then follow "recommended modifications of the above principles for *temporary application under exceptional circumstances*" and the first statement is that "Such connections should not be permitted where the available public water supply or private fire protection supply is adequate for fire protection purposes."

Changes Made at the Factories.

Of the seven factory plants affected by the order for disconnection, five were so rearranged and added to their fire service connections that it was unnecessary for them to do expensive work. In this connection it is also proper to add that the Hartford Water Department did its share toward reinforcing an already excellent system of distribution mains in this vicinity.

Several new gates were installed on the large feeders in order that smaller sections might be cut out without detriment to the service, additional hydrants were installed and a large new feeder main will be led directly into the district affected as soon as a right of way can be obtained under railroad tracks.

Two of the plants chose to install more elaborate works. One of them built an elevated tower of large capacity; and the other, the Underwood Typewriter Co., has nearly completed an elaborate and unique plant which is not duplicated, I think, in this country and is to be used, it is said, as a model for similar systems elsewhere. This plant will use river water only and will be without direct connection to the city supply.

The details of this plant were worked out by the Factory manager of the Underwood plant, Mr. Charles D. Rice, in connection with the Engineers of the Associated Factory Mutual Co. They appear to embrace the

majority of those features that insurance engineers deem requisite for a well protected plant.

Essentially this plant consists of a double-deck steel tank 30 ft. in diameter, and about 150 ft. high. The lower chamber will contain about 600 000 gal. of water which will be kept under pressure for immediate use. The upper chamber, holding about 100 000 gal. will be held in reserve as an emergency gravity supply.

At the base of the tank is a pump-house containing pumps, air compressors and other appurtenances. To guard against freezing special provisions have been made both to heat the water in the tanks, and in case of special necessity to cause complete circulation of the contents by pumping.

Use of "F. M." Double-Check Valve.

In the recommendations of the Committee of the State Sanitary Engineers referred to above, and under Modifications for Temporary Application Under Exceptional Circumstances, the "committee is of the opinion that the most efficient and dependable device developed up to date (aside from the method described in principle No. 1 above, (quoted on page 11 herewith)is the check valve installation recommended by the Associated Factory Mutual Fire Insurance Companies of Boston, Mass."

The author of this paper fully concurs in this recommendation but would suggest the substitution of an all bronze body and valve for the present type, and similar to if not identical with the valve and its accompaniments built for the Hartford Manufacturers from the designs of Mr. Rice, as an example.

As a condition precedent to the installation of these connections for *temporary service only* and covering a stated period, agreement should be made to keep the water department fully informed of any defects that have appeared anywhere in the proper functioning of these valves, and changes in design should be reported both to the plant owner and to the Water Department.

Also both the plant owner and the insurance company should agree to notify the Water Department at once when the risk is withdrawn from the mutual company and placed with a stock company.

This is essential, as the stock companies, being neither so insistent on the use of these connections nor so impressed with their fire protection advantages over other means, either do not inspect them at all or as a matter of routine.

Inspection by Water Department.

Inspection of these contrivances is absolutely necessary, and no water department official may shift the burden from his own shoulders to those of an insurance company and think to have immunity in case something goes wrong. Eternal vigilance here as every where else is the price of success.

At Hartford the inspection at the outset was supposed to be and they

were made conscientiously by the engineer in charge. Then came changes in personnel. For several years the presence of these valves was unknown to the engineer as he was not at that time given control of the maintenance work. When charge was assumed after some time the matter was casually brought to attention and, on looking into it, it was found that the inspections were then of the most perfunctory kind and were often omitted for long periods.

For the last two years of this installation the inspection by the Board's forces was made every week for pressure test, and once every three months the entire installation was taken apart and thoroughly cleaned and overhauled.

The results of this experience have firmly convinced the author that such inspection is absolutely necessary if even a reasonable assurance of safety is to be had.

Thousands of dollars are spent by water departments in sanitary patrol of water sheds, purchase of remote farms on the drainage area, and in all the refinements of the modern filter system, and then they often forget a through connection right at the consumer's door, trusting implicitly in a mechanical device to work perfectly and in a manner such as no other piece of human mechanism has ever been known to work.

Responsibility.

If pollution of the water supply should obtain and an epidemic of typhoid fever ensue, the responsibility for death, disease and impairment of health must rest squarely on those officials who are in responsible charge of the water supply system.

Inspections by insurance employees, no matter how conscientiously performed, and the assurance of insurance engineers, no matter how eminent in the profession, can not relieve the local water man of his accountability to the people to furnish them with a safe water.

In the final analysis by the dependants of the lost one it makes very little difference whether death was due to typhoid fever or by burning. If pollution by the connection is very remote, as is the claim of some advocates of this system, so also is the danger of fire, and surely a water department should not be asked to take even the same chance with the health of the people that is deemed unwise as concerns property loss.

Conclusions.

The PRINCIPLES enunciated at the conference of the State Sanitary Engineers, which is referred to above, are fully in accord with the conclusions that have been reached by me as a result of experience at Hartford and knowledge of similar conditions elsewhere.

I am heartily in agreement with them, because I believe them to be in accord with other provisions for conserving the public health, which are now deemed essential for the protection of a water supply used for domestic purposes.

Discussion.

Mr. Frederic I. Winslow.* I do not think I have told this before, but about fifteen years ago the Town of Hyde Park, then a separate town, had a very serious epidemic of typhoid fever, which no one was able to account for. It went to two parts in the town, a mile apart or so.

About three years later this town became a part of Boston. I went out with some others and found that there were about six mills in town which had two supplies, one from the system in Hyde Park and another from Mother Brook, which is a connection between the Charles River and the Neponset River, and a very filthy stream. We found in one case that there had been a fire just before the epidemic had occurred, and without doubt that was the cause of the epidemic.

Along about that time Mr. Kunhardt, with his able corps of assistants, devised the double-check valve, two checks built into the same manhole. I have learned since that they found in one case where somebody left a pair of overalls in the pipe, and which stretched between the two valves, holding both open, and the water went back into the city system from the private one.

I am glad to heartily endorse the last statement of the speaker.

Mr. J. M. Diven.† I think about the only discussion on the proposition is that no such double connection should be allowed under any conditions, taking no chances whatever on double checks.

Mr. Harry A. Burnham.‡ It has been several years since this matter of Check Valves on private fire service connections has come before this Association, and this may be an opportune time to briefly review the situation as matter of record in the general field of fire protection by automatic sprinklers.

The automatic sprinkler has done more to reduce fire losses than any other single device. In New England these possibilities were quickly recognized in the early days and the efficiency of the fire extinguishing equipments in many communities was greatly increased by supplying these sprinklers direct from the city mains.

Soon the increase in values made possible by this improved protection brought about the need of a more nearly absolute continuity of supply and sometimes of a larger delivering capacity than was afforded by the average water-works system. This need was satisfied by the secondary supplies now found in practically all of the large manufacturing plants in the form of fire pumps, gravity tanks or private reservoirs. This secondary supply to the sprinkler systems brought about the need of check valves on both supplies in order to make available automatically the combined flow from both within the sprinkler system.

---

* Division Engineer, Metropolitan District Commission.

† Secretary, American Water Works Association.

‡ Engineer, Factory Mutual Fire Insurance Co.

This race between values to be protected and water supplies to protect them with has been going on until it is now impossible to place a safe limit on the amount of water which may be needed to extinguish a fire in the large industrial plants of to-day.

This long period of development of fire protection engineering, covering now about forty years, has not been entirely free from accident incidental to the evolution of this science. Unexpected accidents have been comparatively few, however, and their lessons have been well learned. The problems presented by such accidents as the destruction of extensive properties due to inadequate water supply, sudden loss of a number of lives by fire due to the lack of sprinkler protection, an epidemic of sickness or loss of life by disease due to mingling of the water supplies, the starting of sweeping conflagrations due to lack of sprinkler protection, all have required careful consideration in their relation to each other.

In the face of these apparently conflicting problems the earnest endeavors of the water-works men to supply clean water suitable for domestic consumption and at the same time to maintain the high efficiency of the fire protection equipment have been greatly assisted by the development of better safeguards such as filters, chlorinating plants, private pumping plants, special check valves and other devices.

One device which has already done much to reconcile these conflicting problems is the simple swing check valve redesigned to secure thorough reliability in preventing leakage and installed two in series in accessible locations to encourage as excellent maintenance as any other part of the water-works system can receive.

A brief history of the development of this safeguard known as the Special F. M. double-check valve equipment was presented at a meeting of the Canadian Section of the American Water Works Association at Toronto, February, 1921, and appears in the May, 1921, number of the Journal. That article covered the experience of the Associated Factory Mutual Fire Insurance Companies with this particular arrangement of special check valves.

Among the cases of public recognition given in that article are the following:

In April, 1918, the New York State Department of Health accepted this arrangement as a sufficient and satisfactory safeguard, with favorable comment on the Auburn, New York, installations.

In 1919, the State of New Hampshire revised its law relating to Emergency Intakes and Factory Connections to require the use of this safeguard.

In 1921, the Provincial Board of Health of Ontario issued regulations requiring this safeguard.

In July, 1917, the Water Department in Fall River made the ruling that all fire service connections should be protected with the double-check valve arrangement where a secondary supply is from a pump.

At a Conference of the State Sanitary Engineers, held in Boston, June, 1921, a report of the "Committee on Cross-Connections, By-Passes and Emergency Intakes on Public Water Supplies," was accepted and adopted in which the Committee "recognizes the relative degree of safety which can be provided by suitable check-valve installations on connections between public water supplies and a piping system used for fire protection only." "The Committee is cognizant of the fact that such connections may be proper and reasonable under certain conditions," and expresses "the opinion that the most efficient and dependable device developed up-to-date," except complete severance, "is the check-valve installation recommended by the Associated Factory Mutual Fire Insurance Companies of Boston, Mass."

At the San Francisco Meeting of the National Fire Protection Association in June, 1921, in the report of the Committee on Private Fire Supplies from Public Mains, Mr. E. V. French, Chairman, the following appeared among other topics which have been receiving the attention of that Committee for several years:

"Perhaps the most important development under the scope of the committee work is the continued excellent record of the double check-valve equipment above mentioned and described in the National Fire Protection Association proceedings of 1910. Over 500 such equipments are now in actual service in various parts of the country. These are periodically inspected internally and tested for tightness, and as far as is known no case of trouble in public water mains from leakage of these equipments has yet occurred. Information regarding this safeguard has been welcomed by many Water Works and Health Officials as the best solution available for problems in which the conservation of both life and property must be recognized."

From such information as comes to our Inspection Department in connection with our work on fire protection, we gather that the position of absolute prohibition of all cross-connections to unapproved supplies used for fire purposes has been taken by very few, if any, State Boards of Health.

The number of cities taking this position is extremely small, and specific rules or ordinances prohibiting this kind of connection are for the most part non-existent even in cities which are opposed to such connection on general principles.

The list of cities and states which require the special check-valve arrangement is very much larger than the list which actually prohibits their use.

The largest list by far is that of cities in which no definite position either for or against any fire service connection is taken, but which permit the installation of the Special type F. M. double-check valves as a desirable and necessary improvement over old conditions.

A recent count from our records shows these installations now number over 600 in 170 towns and cities in the United States and Canada, and as far as can be ascertained there has been no case of trouble from foreign water in the public mains due to the failure of any of these equipments.

It should be noted that the development of this safeguard together with regular inspections of its condition has made it possible for the large industrial plants of the country depending on the public supply for their fire protection through automatic sprinklers to retain the use which they have enjoyed for years of auxiliary fire pump supplies from large bodies of water, such as harbors, lakes and rivers, and this without any appreciable danger to the quality of the public supply.

As a means of conservation of life and property and avoidance of unnecessary duplication of large water supplies, the Special type F. M. double-check valve equipment in its present form is one of the most valuable contributions made in recent years to Water Works Engineering.

Mr. L. H. Kunhardt.* My friend, Mr. Winslow, did me the honor to mention my name as the one who introduced the special double-check valve. I came over here to-night as I heard of the program, and if I may be permitted to say a few words I should like to add that I think the essential thing in all this work of fire protection, engineering and water supply is coöperation. The owners of property need that coöperation; the waterworks people need the coöperation; the insurance companies need the coöperation. We need to work out a good plan, all of us, of something that is better.

Now, that brings me back to progress. We wish to progress in this work, not to go backward. Hartford was the first city, as Mr. Saville has said, to adopt the special double-check valves. They did a good thing. They did it on the basis of the recommendations of the Inspection Department of the Factory Mutual Insurance Companies. It was the finest thing that was put in at the time anywhere. Those early check-valves were an improvement on the first check valve, the ordinary commercial checks that were made. They were not perfect; we knew they were not perfect. The then Engineer of the Water Board in Hartford knew they were not perfect. The Company that made them had some difficulties in making all the improvements that were desired, but the check valves were put in because they were needed, and served their purpose admirably and well, and they protected the water connections.

Now, another point: If we could have these check valves on every connection — I am not speaking only of fire service connections, but every connection that has any supply from another source available or in use, and that condition exists in a good many cities and towns in the United States — I could mention dozens of them where business blocks, commercial buildings of all kinds, have double supplies of water; driven wells in country towns from which water is put in the same supply line that the city water

* Vice President and Chief Engineer, Boston Manufacturers Mutual Fire Insurance Co.

's going into — we would then have real security against pollution. Sometimes they do not have check valves of any kind or description. These are the most liable sources of contamination.

My friend, Mr. Winslow, mentioned Hyde Park. There were dozens of poor connections in that city other than those two or three in the mills. The mill connections were better protected than the others were, — there is no doubt about that. As soon as any water board, or engineer of the water works, in any way, shape or manner expresses a desire to have these old conditions changed, they are always ready to change them. I o not think there has been a single case where they have not been put in when they were asked for. The owners of property are glad to coöperate, and I am sure, as has been already stated, that you will find no lack of coöperation on the part of the fire insurance engineers in this country.

Now, about this reported leakage that occurred in Hartford, Conn.: We never heard of it until long after. It was in some of the old type check valves which were fixed over to make a fairly acceptable device. We never recorded in any of our tests a leakage of a double-check valve. Now, I say that advisedly. The double-check valve was put in for the very reason that one check valve might leak and the other one would not at the same time. That is what it is for. If one check had been enough they would not have put in two. There has never been a case of leakage back through the improved double-check valves, such as are approved and recommended.

The case cited at Lowell was so far from having anything to do with this proposition that we have before us to-day that it hardly needs to be mentioned. It was simply a case of a check valve designed many, many years ago, in a pipe which was not in use. The check valve had been taken out at one time when the canal was under repair, and laid out on the bank of the canal. It was a type of check valve that, when you turned it over upside down and put it back again, if you did not happen to put your hand inside and push the clapper down it might not go down, as I understand it, and when they put it in the pipe they left the clapper wide open. It was on an emergency connection. Now, the big fire came along when they needed all the water that they could get; 15 000 gallons of water per minute, I believe, were pumped into that fire. They needed every drop of it. They saved the mill. And they opened the gate valve to get the water from the city connection into the fire lines of the mill, and after the fire was over they did not get that gate valve closed quite as quickly as they might, and there was some water pumped back into the mains in Lowell, so far as is known. But it was through practically an open pipe. There was no real check valve on the pipe at the time it was pumping; just simply an open pipe back into the city main.

That is a condition, gentlemen, that exists in lots of places. You have open pipe connections in your cities and towns. They ought to be investigated. I wish you could have more of these special double-check services, rather than to stand back and say you won't admit them, and then allow

the present conditions to go on which are a serious detriment to the health of the community.

Now, be careful not to draw a wrong inference. Be sure and get all the facts. I just want to leave that thought in your minds before I sit down. I have in mind always that we want to progress, and here is a device distinctly better than anything else that has ever been installed in some of these big manufacturing plants, which need, not two, three or four thousand gal. of water a minute, but they need ten, fifteen or twenty thousand gal. of water a minute to do business with at a fire, and you can't find that supply ordinarily in a gravity system from 50 to 75 lbs. pressure, which is the normal pressure which exists, probably, in ordinary street mains of the cities and towns. Of course there are places like Fitchburg where they have very high pressure; also Worcester, and others that might be mentioned. But the ordinary pressure of 50 to 75 lbs. is pretty good for sprinklers and water supplied by hydrants until there is a big draft, and then you find the pressure falls off even with the mains of quite good size.

So I say, let us work out the problem of safeguarding these big industrial plants. In New Bedford there has been the finest kind of coöperation between the mills and the city water-works officials. When a mill is proposed the city lays down the big pipes and the mills put in the fire pumps 1 000 to 1 500 gal. pumps capacity per minute — not one or two but often three of four — making connections to the adjoining mills, so that there may be 10 or 12 of these pumps, in addition to all the water that the public water works can supply. They gladly fall in with the proposition and recognize the importance of the double service. Without this double service in Hartford the protection is now seriously curtailed.

Now, this double protection is none too adequate, if you get a sweeping fire at work in the vicinity of one of these plants. You have the same thing in Lowell, Lawrence, Manchester, and other big industrial centers in the country, and also in small communities. We need all the water that we can get and that it is possible to have at a high pressure for the proper fire protection and safeguarding of these plants. I think the property owners in a city or town have a right to this protection when they build these big plants on which the success of the community and its welfare depend. I thank you.

Mr. Diven. Unquestionably the double, or F. M., check valve is a great improvement over the old form, especially as the old ones were frequently buried in the street with no means of getting at them for examination. But even the most improved check valve cannot be relied on without careful, systematic and frequent inspection, and here the human element comes in — will they have such inspection? Or will they like many other water-works appliances be installed and then forgotten so long as they continue to work or seem to work all right.

It always seemed to the speaker that the mills and factories can have full protection without in the least endangering the domestic supply, this by installing entirely separate systems for the two sources of water supply, two systems with absolutely no physical connection. This would cost something, but is not the safety, the health and lives of the water users in a city worth the cost? It is urged that such dual supplies are not entirely safe, that the impure water lines may be tapped in the mills and used by employees in the mill or factory. True, but this would endanger the lives of only a small part of the community, would not contaminate the water in the mains from which the entire population draws its supply of drinking water.

The mills and factories are entitled to the fullest possible protection, it is good business to give it to them as the prosperity of the community depends on them largely. This applies to a water company as well as to a municipal plant, for the prosperity of the water company depends on that of the community.

MR. PATRICK GEAR.* The gentleman spoke about the improved double-check valve. What improvement is it over the old one that was made forty years ago? Who makes the improved check valves?

MR. BURNHAM. Those check valves are made by the Chapman Valve Company of Indian Orchard, Mass., the Fairbanks Company of Binghamton, N. Y., the Ludlow Valve Mfg. Co. of Troy N. Y., Pratt & Cady, of Hartford, Conn., the Grinnell Company, of Providence R. I., and Jenkins Brothers of Montreal.

MR. GEAR. I have bought all of them. I worked in a machine shop before becoming Superintendent of the Water Works. I took those check valves apart when they were new, and after that for twenty years, and got some of the new ones last year and took them apart to see where the improvement was, and I can't see it.

We have check valves that were installed in 1893, around the mill where I was working at that time,—a check valve set in a 12-in. line, and last year we had occasion to shut off that same line and the check valve was tight. This is not one of the new ones that was put in five or six years ago.

In one case the meter commenced running backwards. There was a check valve on the line and the clapper was up in the air. It was one of the new ones.

MR. DIVEN. While I rather condemn the use of the check valve, I have used them, and I will say that the ones I have seen lately have been a decided improvement, having a soft rubber face which makes a tight joint, and the addition of the second check valve makes it possible to make an inspection of both valves with very little trouble to see that they are tight.

MR. GEAR. If they can tell me where the brass clapper of this check valve is a quarter of an inch away from the cast iron, I will admit that they have improved it. It does not give a quarter of an inch clearance on the

* Superintendent Water Works, Holyoke, Mass.

sides. Corrosion occurs there, and it holds the clapper up. That is why they have to inspect and clean them every year.

Now, if they will make a check valve that will have a good clearance all around, and all brass, so much the better, as with good space on the sides they will close properly. But they have not made them that way yet.

Mr. Kunhardt. I would like to say to Mr. Gear, that if he will look at the installation at the American Thread Co., in Holyoke he will see valves there that have probably $^3/_4$-in. clearance between the iron and the brass. I think the installation will prove very pleasing to you, and certainly very much better than dozens and dozens of connections in your city. It is the best safeguard that has been installed in Holyoke for years, and is fine.

Mr. Saville. This Rice valve that I spoke of is an all bronze valve; the clapper seat and the housing,—everything is bronze. And aside from that, there is a pocket below the valve which is designed to catch gravel or anything of that kind, that may come through. The rubber that is put on for the facing was specially designed.

Mr. Rice, previous to being Manager of the Underwood Typewriter Company, was Superintendent for a great many years of the old Columbia Bicycle Works, and as such he had a great deal of experience with rubber, and was much interested in developing a rubber gasket that would have many advantages over the rubber that you could get.

Another thing that comes up is the fact that no matter how good the inspection of the Factory Mutual people, inspecting the valves perhaps once or twice a month, or once or twice a year themselves, there is another serious defect. In Hartford one or two concerns that formerly had these check valves, and were at one time Factory Mutual risks, gave up their allegiance to that company. When the Factory Mutual Inspectors ceased to inspect those valves no notice was given the water department. I think that is true, is it not, Mr. Burnham?

Mr. Gear. I have been advocating for ten years both a check valve and a gate valve, that would have sufficient space between it and the cast iron.

Mr. Winslow. We are all extremely gratified to see Mr. Kunhardt, Vice-President and Chief Engineer of the Manufacturers Mutual Ins. Co. present, and it is our loss that he is not yet a member of our Association.

No one appreciates more than the speaker the effective and splendid achievements of his company for the past thirty years, under the leadership of the late Edward Atkinson, Mr. Joseph P. Gray, and my friend, Mr. Kunhardt, with whom I used to clash while at City Hall, Boston, and I always realized, as we all must, that the underwriters and the water-works men must coöperate in the matter of fire and sanitary protection. The only point at issue — and this has not yet been fully answered — is whether the water-works man can afford to take the risk of possible contamination of the water supply, however remote that may appear to be. That is,

how can we be certain that both of those check valves will never be open at the same time?

Mr. Diven has anticipated me in suggesting that the double supply be permitted, but without physical connection, a method probably too expensive ordinarily; for one main point in getting mill owners to insure is to make the cost as low as is consistent with safety.

The solution may perhaps lie in some form of local purification — in the mill or factory — of the secondary source of supply, by chlorination, copper, or other chemicals.

Mr. H. O. Lacount.* Being one of those that was in on this matter at the very start in Hartford, I have watched the progress and development there with a good deal of interest, and have listened to Mr. Saville's paper to-night giving the conclusion on the matter in Hartford with equal interest. It seems to me that while they have reached their conclusion there deliberately and definitely, that perhaps does not indicate the general verdict, because, as we have heard from Mr. Burnham's paper, there are a goodly number, and an increasing number of those who are giving recognition to this method of safeguarding the water supplies.

I have noted two things from my own observation: First, that the water departments are appreciating more and more the importance of safeguarding the public water; and secondly, that real headway is being made year after year in the use of this particular method of safeguarding the water, namely, the double checks of this special design.

Referring to Mr. Gear's remarks, I am very sure from what he said that he has not yet had the privilege of seeing one of these special valves, because they do have $\frac{3}{4}$-in. clearance around the clapper, between the clapper and the casing, with the direct object of furnishing more clearance than in the regular commercial check so that the clappers will not be hung up so easily by incrustation and corrosion of the casing itself.

Another feature of the valve I may say at this point, is the bronze clapper and the bronze clapper arm, as well as more distance between the bronze valve seat and the cast iron into which the ring is set. I am satisfied that there is a very definite improvement in these special checks over the so-called commercial checks, of which you will find so many thousands in use. And when you consider the care with which these are installed, and I am glad to say, the care that is taken of them after they are installed—we have improved conditions very much, and I think that is being appreciated by a good many of the water-works people.

Mr. Diven has brought up a point which I have had in mind, and that is the human element. There is the human element involved in the care and inspection of the valves, the valves being definitely designed to facilitate that inspection, making it as easy and convenient as possible to open them for inspection and cleaning. But the human element is not absent in a great many of the other water-works problems. You have a chlor-

*Engineer and Assistant Secretary Inspection Dept. Associated Factory Mutual Fire Ins. Co's.

ination plant. I have an idea that the human element enters very much in the chlorinating room. And you have a filter plant, and a great many times if not always there is a by-pass around the filter bed with a valve in the by-pass. It is put in there to operate under certain conditions. The human element may function wrongly there and leave the valve open at the wrong time.

So that we cannot eliminate the human element from our problem. It is here, and it is in a great many other places and conditions that the water department and everybody else must reckon with. So there is a real point in this coöperation that Mr. Kunhardt speaks about, and the appreciation of the value not only of property but of life. We may not gain so much as we think by going to the extreme point in any direction, if by doing that we cut down the protection which otherwise would have been provided. To discourage the installation of sprinklers by making it difficult to get a proper water supply, is to endanger the lives of those in the buildings not thus protected.

I think there are several sides to this question , which must be carefully considered before it can be regarded as settled. I am reminded that two years after this method was introduced in Hartford we had a meeting of the New England Water Works Association and this matter was discussed. It was somewhat of an experiment at that time, and we were speculating as to what would be the result. Six years later, in 1916, it came up again and was discussed at length. Now after another period of six years this subject is again on the program. Six years from now we may report more progress one way or the other. It is a matter which has received a great deal of attention and has a reasonable recognition already, and I think it is going good work.

Mr. Diven. While it is true we can't eliminate the human element entirely, that is no reason why we should not eliminate it as far as possible. Personally I believe in the double-check valve if it is properly handled, and in any event it is a very great improvement over the old style buried and uninspected check valve.

Mr. Saville. There has been considerable said about coöperation and advancement. I fully agree with that, and I think we all do. We are all here for that purpose, — to see what is the other fellow's viewpoint and do as much as we can to work in harmony. It seemed to me, however, that coöperation and advancement might mean only approval of the double-check valve. So far as I know, none of the other insurance engineers except the Factory Mutual people are so insistent on this double-check valve proposition. All the other insurance engineers, the stock companies particularly, are fully satisfied with tanks of large capacity, or with cisterns into which city water can be brought through a large pipe, as large as required, and in case the auxiliary system breaks down the city water is available.

The only thing I can see in favor of the double-check valve system is the matter of cost of installation. I think in Hartford, with the manufacturers the question of the cost was not a consideration. Some of them have spent thousands of dollars in getting a supply that would conform with what was wanted by the Water Works. And on the other hand, a double-check valve system, just two checks and the little apparatus that goes with it, is very much cheaper than a good, big tank, or a cistern of large size, and if an insurance man can go to a manufacturer and say, "You can get secondary protection with check valve and cross-connections for \$500 or \$600 or \$1 000, where you would have to pay \$10 000 or \$15 000 the other way," it is a big argument in his favor.

Now, two of the largest manufacturing plants in Hartford have had large underground cisterns. I am informed that these manufacturing plants are getting as low insurance rates as those that formerly had the double-check valves.

In discussing this matter at one time Prof. Whipple said that practical water-works men and health officials generally were opposed to this method of connecting up a supply, that there was undoubtedly some danger in it.

Mr. Diven. Do you know of any plant having a double pipe system?

Mr. Saville. No, I do not.

Mr. Diven. I have heard of one. Do you think the cost of that would be excessive, out of reason?

Mr. Saville. I should think it would, and also that there would be a great deal of danger inside the building of connecting up those pipes by the plumbers. For instance, I was talking with sombody who said they tested a system and it was thought all the valves were closed, but they could not seem to get the system dry. A thorough inspection was made and they found, unknown to the managers of the plant, that a plumber inside of the plant, in order to get some water to test out some plumbing had made a connection between a secondary supply tank and the regular system. There is an example, of the danger of two supplies.

Conclusion of Discussion.

Caleb Mills Saville (*by letter*). The author is much pleased with the discussion which his paper has provoked, and is particularly gratified at the presence and participation of the Engineers of the Factory Mutual Insurance Company.

Such discussion cannot fail to make all of us see more clearly the veiwpoint of the other and so pave the way for that better understanding which reacts to the mutual advantage of the interests which we serve.

Mr. Winslow has performed a distinct service to the cause of pure water in putting on record the episode of the overalls stretched between the two check valves on the cross connection, and holding both of them open.

Hitherto statements refering to the danger of such a happening, usually have been flippantly brushed away, with the remark, that while anything might happen, such a case had not occured in the past, and with the double-check valves it was too remote for consideration.

An actual condition and not a theory is now described and is uncontroverted by the representatives of the Factory Mutual Insurance Companies, who are the particular sponsors of the type of fire protection, which uses the double check-valve connection.

The sequence of events is also interesting: the double-check valves on connections between the city supply and a foully polluted secondary source of water supply, and the use of the mill pumps for fire protection preceding the epidemic.

Whether or not the particular water which passed through the open double-check valves was responsible is immaterial. The fact remains that the protection relied upon for such an emergency did not work.

Such a condition would probably be considered as proof so reasonably presumptive in a court of law as to warrant the placing of the responsibility on the water department that knowingly allowed the existence of such an opportunity.

In the discussion of this paper and in articles elsewhere favoring the use of cross connections controlled by double-check valves, the efficacy of sprinkler systems has been interjected and considerably stressed, as if they and cross connections were inseparable.

While the value of sprinkler service for protection against fire must be fully acknowledged by all well informed persons, it has not been made clear what is its place in a discussion of the question as to whether or not a check valve controlled connection is or is not desirable between an adequate city water supply and a polluted source.

The principal value of sprinkler service is *prevention* of fire by extinguishing a blaze in its incipiency and *before* it can spread. For this purpose comparatively limited amounts of water are required.

Insurance engineers generally place little value on sprinkler service *after* a conflagration has gained headway; and the opening of hundreds of sprinkler heads, with their continuous and promiscuous discharge,. after a building has been gutted by fire, may so reduce pressure in street mains as to seriously interfere with proper fighting directed by brain rather than by chance.

Experience at the Salem, Mass., holocaust 1914,* offers unimpeachable testimony supporting this assertion.

Unless there is some peculiar virtue in sewage for fire extinguishment it would seem that an amount of water adequate for sprinkler purposes might better be had from an elevated tank of proper size or from an underground cistern. Into either of these city water in any quantity desired can be run without dangerous connection with a disease ladened water course.

* Page 97 JOUR. N.E.W.W.A. Vol. XXIX, 1915.

I am led to lay particular emphasis on this point, because so far as I know, no sound argument has ever been presented by advocates of the double-checked cross-connection in support of that means of serving a sprinkler system as against an adequate supply of water from a cistern or tank of proper size.

Proper size would be defined as that size which a majority of experienced insurance engineers would consider reasonable.

As to yard hydrants that is a different matter and it seems to be clearly evident that increase in efficiency is best served by a separate system into which a secondary supply can be pumped from a source of unlimited capacity.

Even in this case, however, the practical need of an automatic connection with the city water mains has not so far as I know been demonstrated in fact.

The installation of such safeguards as filters, sterilizing plants, and sanitary control of water sheds at the entrance to the distribution system is all for naught, if inside that system there is a connection with a public sewer, under automatic control, which in time of remote emergency may fail to function properly.

Because filters may be by-passed, sterilizing apparatus get out of order, and chance pollution invade a water storage reservoir, there are no arguments for knowingly allowing connections which at best can be made to operate only by constant attention.

Modern sanitary safeguards aim to protect public health by the most efficient known means. The fact, that being of human contrivance, the methods are not always infalliable, certainly offers no excuse for consciously adding one more opportunity for contaminating a water supply.

The specious reasoning, that makes use of such fallacious and subtle arguments, indicates a tendency to sophistry that should serve to discredit it in the minds of thinking persons.

As to the reference of Mr. Burnham to the approval of State Boards of Health: —

Replies of many State Departments of Health from all over the country in answer to a questionaire sent out by the Hartford Water Department in reference to this matter, and particularly including those that allow the use of the double-check connection, indicate very guarded approval, and none of them seem to place implicit confidence in them. "They are better than nothing." These answers are on file.

In some cases limited approval has been given, in others peculiar circumstances were considered, and in others matters of "expediency" or of "public policy," appeared to control.

The *complete* statement of the principles enunciated at the State Sanitary Engineers Conference at Boston, refered to by Mr. Burnham and mentioned by the author of this paper on page 12 of the text, is added to the paper as Appendix A.

As to the statement "that so far as is known no case of trouble in public water mains from leakage of this equipment has yet occured," it seems unnecessary to comment or to trace the exact path of the particular disease germ when such cases as the Hyde Park overall incident and the leaking check valves at Hartford are of record.

The statement that "so far as can be ascertained there has been no case of trouble from foreign water in the public mains due to failure of any of these equipment" seems a perfectly safe one to make, but difficult of substantial proof either for or against. It is, however, no conclusive argument because in Hartford and probably elsewhere most of these connections have never been subjected to practical service conditions. In the one case that we have of record, however, Hyde Park, there was probable evidence that they did fail to function when the call came.

As indicative of the general attitude of fire insurance engineers, a statement of Mr. Geo. W. Booth, Chief Engineer of the National Board of Fire Underwriters, is quoted (*Engineering News—Record*, June 17, 1920):—

"Insurance standards require, for complete reliability two independent sources of supply, and the plant management, or the municipal authorities may, and often do, use one source which is unsafe or questionable from a sanitary standpoint, for the reason that it is a cheaper or easier one.

"The engineers of the National Board of Fire Underwriters do not, and we believe other engineers should not, favor such connections, but it is not possible, without charge of discrimination, to refuse credit for them as emergency sources.

"It is, however, standard practice with many of the insurance bureaus to recommend secondary sources of supply which will be safe, as for instance a storage reservoir."

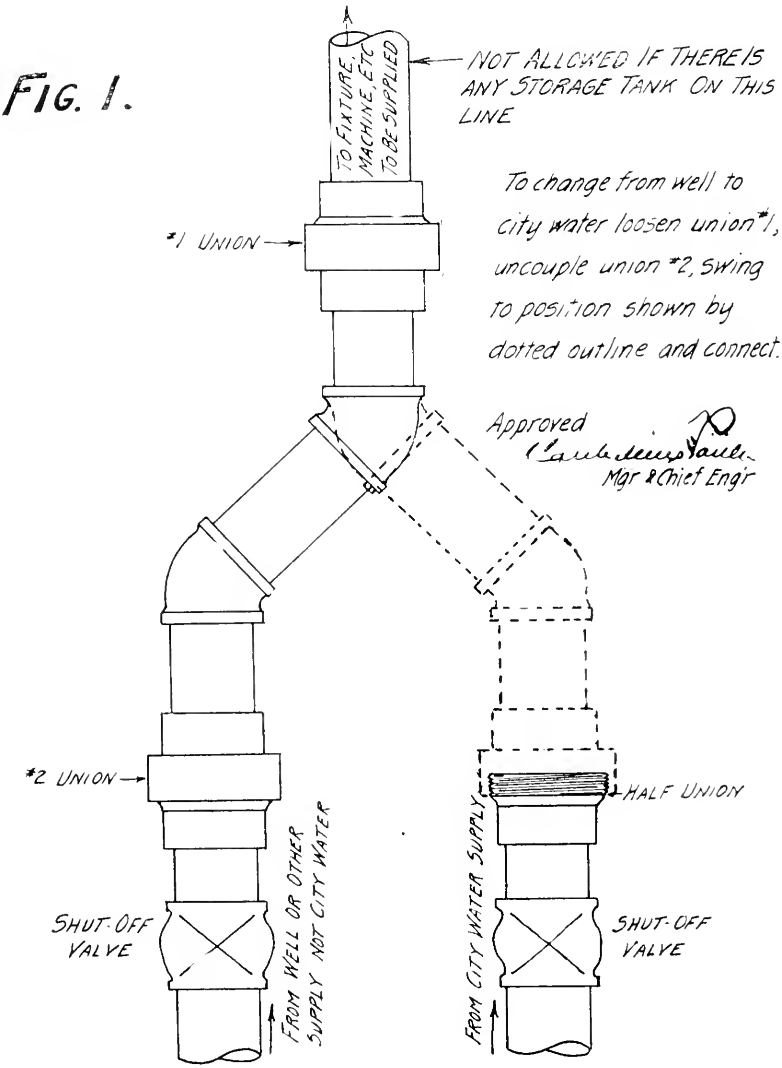
Mr. Burnham speaks for the installation of the double-check valve installation as a means of avoiding unnecessary duplication of large water supplies. If a municipality knowingly and deliberately balances dangers of pollution of its water supply against the cost of proper fire protection, including both water system and public fire department, there is no argument. The city should have what it desires, but its authorities cannot shift responsibility. They, and not the insurance company, are to blame in case of trouble.

If, however, a city is willing, as Hartford has ever been, not to count expense in keeping its water system up to the best modern standards and in providing a fire department which is recognized by authorities as "equal to the very best in the world" it would appear from the antecedent proposition of Mr. Burnham that double-check valve, cross-connections were unnecessary.

I am glad that Mr. Kunhardt has spoken of coöperation, as it gives me a chance to tell what Hartford's Board of Water Commissioners did for reinforcement of a water supply system in the factory district, although it was previously amply adequate.

In order to segregate smaller districts, in case of a large fire, with broken mains and factory standpipes bleeding the system, two 24-in. gates and 6 gates on 10 and 12 in. lines were installed; four new hydrants were located; permission was given for two new fire connections of larger

FIG. 1.



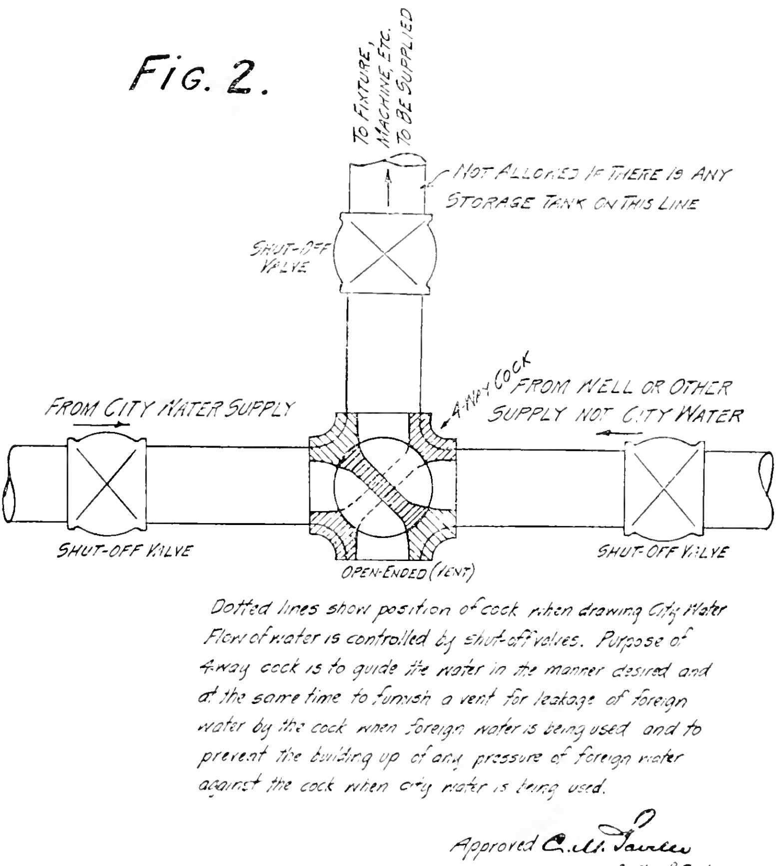
size than usually allowed, and promise was made to install a 16-in. connection about 1 100 ft. long as soon as right of way is given by the city, making an entirely new connection into the district.

No drastic steps were taken in the enforcement of the order for disconnection, and the factory owners were given their own time to complete changes in their works. It is proper to state, however, that on their part

the factory managers made every effort to comply quickly with the desire of the Board.

For manufacturing purposes a connection was deviced (Fig. 1) which while allowing full use of a private supply was easily manipulated to supply city water in case of need, and yet provide absolute safety by complete severance. No stand-by charge is made for this service.

FIG. 2.



Another device (Fig. 2) was proposed, which also seemed to afford absolute safety and yet be ready for use when needed. This was not approved by the Board because of its desire to have complete physical separation of its water system from that from any other source.

As to progress, also urged by Mr. Kunhardt, it seems to the author that progress and coöperation between the public health and the fire insurance interests must work toward that which is advantageous to both, that is what is ordinarily meant — the getting together for mutual advantage. There is no coöperation when the giving is all on one side.

Open-minded consideration of standard means for furnishing the secondary supply, ample service from the city system, large-sized mains, abundant hydrants, and a disposition to consider the faults in both the private and the public demands in an impartial manner, seem to me to be among the guide posts along the path of coöperation in this matter.

If, however, the first regard of some of the insurance interests is in getting maximum protection at lowest cost, with public health a secondary consideration in this coöperation, I fear that unity of action is still a long way off.

Mr. Kunhardt argues that the double-check valves installed in Hartford in 1908 and continued till the present time, "protected the water connections." This seems a rather more definite statement than the actual facts would warrant. From the records as stated above the double checks at Hartford leaked, and leaked more or less continuously, both at a time and singly, and protection of the city supply certainly was not enhanced by danger of the condition mentioned by Mr. Winslow.

During the Hartford period of experience with the check valves, no fire was reported from any of the factories which was of sufficient magnitude to put the fire pumps in use and bring service conditions against the check valves.

So far as is reported with the old style check valves in service prior to the installation of the "F. M." type, and that, too, for many years, there likewise never occured a condition which tested these valves.

A point is made of the readiness of the Factory Mutual Engineers to make changes in the connection when suggested by the local water department.

Water-works officials are often not so well informed as are the insurance engineers of the failures of protective devices, and in some cases absolute dependence is placed on the periodic inspection of the engineers of the insurance company.

It appears that the spirit of coöperation which is urged should at once take up with water departments any apparent failure of these connections, advise of their improvement and insist to mill owners that changes be made for the protection of health as well as for protection against fire.

At Hartford the Factory Mutual engineers now say that the valves were of an older type, but no notification was given that a better design was even then being installed at Holyoke, only a short distance away.

An outstanding feature of Mr. Gear's discussion is the fact that the insurance company engineers apparently found some radical defect in one or more of the check valves at Holyoke, but did not think it necessary or desirable to inform the water department that they were making changes which affected a connection between the city supply and a polluted secondary supply.

As is generally understood, a prime requisite of coöperation would seem to be a conference, if something is to be done which affects interests of two or more persons.

The Lowell check valve that failed is said to have been the best of its kind, and money was not spared in its construction; the "F. M." valves installed in Hartford in 1908 were claimed to be the best of their kind and proposed as a substitute and equivalent for complete separation of services; both of these types are now condemned.

How soon the present improved design may go to the discard no one can say; but it is to be hoped that its passing may not be brought about by a duplication of the Lowell catastrophe.

As stated above the author believes that progress in the safeguarding of big industrial plants is a vital obligation on the city, which demands adequate water mains, duplicate if necessary, proper pressure for fire fighting and an efficient fire department.

"APPENDIX A."

CONCLUSIONS OF THE COMMITTEE ON CROSS-CONNECTIONS, BY-PASSES AND EMERGENCY INTAKES ON PUBLIC WATER SUPPLIES.*

The Comittee on Cross-Connection By-Passes and Emergency Intakes on Public Water Supplies, after several meetings and full consideration, recommends the adoption of the following definitions and principles:

A. Cross-Connections.

Definition: — A "cross-connection" is a physical arrangement whereby a public water supply system is connected with another water supply system either public or private, in such a manner that a flow of water into such public water supply system from such other water supply system is possible.

Principle No. 1. No cross-connections should be established or maintained between the public water supply system and any other water supply system, private or public, unless both water supplies are of safe sanitary quality and both supplies and the connection thereof have received the approval of the State Health Department.

Principle No. 2. In cases where it is necessary or advisable to supplement an impure private water supply with the public water supply distributed in the same piping system, the public supply must be made available by delivering it into a cistern, suction well or elevated tank, at an elevation above the high water line of such cistern, suction well or tank.

Recommended Modification of above principles for temporary application under exceptional circumstances.

While the Committee is of the opinion that absolute safety demands such complete separation of the public water supply system from other water supply systems delivering impure water, the Committee recognizes the relative degree of safety which can be provided by suitable check-valve installations on connections between a public water supply and a piping system used for fire protection only.

The Committee is cognizant of the fact that such connections may be proper and reasonable under certain conditions, and desires to express the following requirements which should be met in making and maintaining such installations:

1. Such connections should not be permitted where the available public water supply or private fire protection supply is adequate for fire protection purposes.

---

* From the Report of the Committee on Cross-Connections, By-Passes and Emergency Intakes on Public Water Supplies." Conference of State Sanitary Engineers, Boston, Mass., June 1, 1921.

2. That the fire protection piping system shall not be connected with any other piping system upon or within the property served, and that there shall be no outlet from such fire protection piping system except through sprinkler head, fire plugs and hose connections. This requirement is intended to prevent a flow through check valves except at times when a sprinkler head, fire plug or hose connection is open.

3. The cross-connection shall be equipped with such devices as can most effectually prevent an inflow of water from the fire protection system to the public water supply system.

4. The Committee is of the opinion that the most efficient and dependable device developed up-to-date (aside from the method described in principle No. 2 above) is the check-valve installation recommended by the Associated Factory Mutual Fire Insurance Companies of Boston, Mass., consisting of two gate valves with indicator posts, two check valves of the Factory Mutual type, with drip cocks and gages for testing, an alarm valve equipped with a recording pressure gage, a by-pass meter around the alarm valve, all to be placed in a vault of water-tight construction accessible to ready inspection.

5. A systematic test inspection of the cross-connection, including periodic examination of the interior of the check valves, by the Department in charge of the public water supply system must be provided, without which inspections the installations of the cross-connection would be a highly dangerous health menace. The inspection must therefore be made reliable, thorough and responsible.

6. The Committee views as a self-evident requirement that in every case where a cross-connection is being considered for action, a thorough investigation will be made as to local conditions and as to the necessity and advisability of the cross-connection, and that the local municipal officials will be made fully acquainted with the circumstances and given due opportunity for presenting their opinions.

SOME COURT DECISIONS INCIDENT TO THE PURCHASE OF THE BRAINTREE WATER SUPPLY CO.

BY HENRY A. SYMONDS.*

[*September 13, 1922.*]

The subject of this paper is now ancient history, but there are some points relative to the legal phases of the controversy which I will describe that may be of interest and undoubtedly remain as strong precedents for future cases of this nature.

The case mentioned is that of the purchase of the water works of the Braintree Water Supply Co. by the Town of Braintree in the 80's.

To make clear the points to be brought out in this paper, it may be well to here state them briefly. The Court rulings seem to establish the following:

First: That a municipality, acting under the common form of charter rights relative to the purchase of a public utility, and having once taken a formal vote to purchase, cannot subsequently rescind such a vote.

Second: That water cannot legally be drawn for municipal or other purposes from an underground supply having as a source, as part of its supply, a pond or stream in which no right of the municipality or company exists.

Third: That selectmen of towns have regulatory supervision only over streets, but the rights of such a Board are not sufficient to prevent a public utility acting upon such streets in accordance with its charter.

Fourth: Cash or other payments for stock are not necessary to the legal organization of a public utility with Legislative charter.

In 1885 the town of Braintree had become somewhat interested in the question of a water supply and obtained an Enabling Act jointly with the towns of Randolph and Holbrook, in which right was given to each to act independently of the other in establishing water supplies, and taking a portion of the water from Great Pond in the towns of Braintree and Randolph, also the customary right to take water from other sources.

In general, the provisions of this act were the usual ones that had been incorporated into Enabling Acts up to this date, with a few minor exceptions. The Town Enabling Act was accepted, but no further action was taken to install a water supply, and in 1886 the Legislature passed an act incorporating the Braintree Water Supply Co., under the usual terms, but giving the right to take water from Great Pond contingent upon permission of the Town of Braintree. Section 10 of this Act is as follows:

"The said Town of Braintree shall have the right to, at any time during the continuance of the charter hereby granted, purchase the fran-

* Consulting Engineer, Boston, Mass.

chise, corporate property and all the rights and privileges of said corporation at a price which may be mutually agreed upon between said corporation and the said Town, and the said corporation is authorized to make sale of the same to said Town. In case said corporation and said Town are unable to agree, then the compensation to be paid shall be determined by three commissioners to be appointed by the Supreme Judicial Court upon application by either party and notice to the other, whose award, when accepted, by said Court, shall be binding upon all parties. This authority to purchase said franchise and property is granted on condition that the same is assented to by said Town by a two-thirds vote of the voters present and voting thereon at any meeting called for that purpose."

This company began constructing a water works plant during the summer of 1886, completing a filter gallery on the shore of Little Pond in Braintree, laying pipe lines and supplying the Old Colony R. R. Shops.

During the Fall of 1886, a strong sentiment developed in favor of town ownership of the water works. At a meeting called on January 12, 1887, the Town voted to purchase the corporate property, rights and franchise of the Braintree Water Supply Co. At an adjournment of this meeting, a committee was appointed who were to confer with the officers of the water company, examine their books, and get from them a price at which they would agree to sell their holdings.

Shortly after this meeting, the committee met the officers of the water company as directed and requested them to state the price for which they would sell their property. The company was not ready to fix a price but offered to submit a written proposition, which was done in a communication dated February 8, 1887, offering to sell their franchise and corporate property for $23,000, with the provision that the Town assume all obligations of the company.

It was further stated that the company had, previous to the meeting of January 12 and before any obligation of any character had been assumed by the company, offered to sell to the Town its franchise. This offer was not accepted and the company had subsequently (in 1886) made a contract to build a complete system of water works, the cost not having been fully determined, but to be contingent upon the development of the work. An estimate was made of $129 000 which, added to the price for the franchise, was estimated to make the total cost to the Town about $150 000.

In the last paragraph the company reserved the right to "withdraw this proposition after 30 days from date thereto unless the same shall have been accepted by the Town."

The committee submitted a report to the Town at a meeting called on February 23, 1887, but the Town failed to take action except to accept the report. On March 1, a notice was sent to the Town by the company that they would apply to the Supreme Judicial Court for the appointment of commissioners to determine the amount to be paid the company by the Town, unless prompt action was taken by the Town. On March 9 such a petition was filed.

The men actively interested and acting for the Town and for the company, were of unusual capacity, representing the highest professional and business standards.

It is evident that, following the report of the Committee, the Town, having learned that the company had made a contract to build a complete system of water works, and feeling that such a system, built under a contract which they were to inherit, might not be in accordance with the plant they wished to build, had gradually become dissatisfied with the arrangements and decided that it was wise for the Town to withdraw.

At a town meeting called on March 10, 1887, it was voted to rescind its vote of January 12 to purchase the property of the water supply company, and it was further voted to proceed to build water works under the Act of 1885, the Town Enabling Act. On March 23, 1887, a Board of Water Commissioners was elected. On May 26 of the same year the petition for the appointment of commissioners was heard before Judge Walbridge A. Field of the Supreme Judicial Court with counsel for petitioners, Hon. Robert M. Morse, Jr., and Marcus Morton. For the respondents appeared the Hon. Edward Avery and the Hon. Benjamin F. Butler. Such an array of legal talent insured a most interesting hearing and there followed a trial which has probably few equals in cases of this kind.

The testimony in this case covers approximately 240 pages and only a few points can be touched in this paper.

Mr. Morse, for the petitioners, presented the case of the company, claiming that the Town had, by its vote of January 12, legally purchased the water company franchise and property and could not withdraw from this act, and, therefore, that the vote of March 10 was void. The attorneys for the respondents claimed that the vote of January 12 was not a vote to complete the transaction; that it was only the first move toward buying the works; that the phrase "that the Town would purchase" intended to imply that a contract would be completed if satisfactory terms were made. They stated that the Town had no knowledge of the contract to build works and, therefore, could not be legally holden by a vote of this nature. They even argued that the organization of the company was not a legal one; that, as the stock which had been subscribed for had not been paid for in cash, the company had no standing. It also claimed, that, as the company had turned over to the contractors as payment for completing the water works all of the stock and bonds of the company, the company had nothing to sell and, therefore, no such purchase could be made. It was argued by Mr. Avery that as the company had disposed of its stock and bonds that the Town could not interfere with the rights of outside holders of these securities.

Mr. Morse gave a very convincing closing argument to prove that the Town, having once voted to purchase the works under the provisions of the Act, could not withdraw from that position.

After considering the evidence and testimony, Judge Field did not allow the petition, and a ruling to this effect was given in June, 1887.

Although the Town had appointed a Board of Water Commissioners, and voted to authorize an issue of $100 000 in bonds to build separate works, no action had been taken previous to the decision of Judge Field.

On September 8, 1887, the water commissioners entered into a contract with a local firm, to complete a system of water works having the source in Great Pond, and work was subsequently strated upon this second system of water supply for the Town of Braintree. The water company, however, continued to operate, through its contractors, in constructing a system from the Little Pond source.

The next move was by the Town, through its Board of Selectmen, who gave formal notice to the contractors to cease delivering pipe and digging up the streets of Braintree for the purpose of laying pipe.

The contractors, believing they had legal rights to proceed, refused to discontinue work.

The Town then attempted to bring an injunction restraining them from operating in its streets.

A verbal ruling was given by Judge Charles Allen, of the Supreme Court, to the effect that the company was operating within its rights and could not be enjoined to prevent the exercise of its charter rights; that the authority given the Selectmen by the charter must be considered regulatory only.

Meantime an appeal from the ruling of Judge Field had been taken to the Full Bench of the Supreme Court, and on April 7, 1888, Judge Knowlton of that court rendered a final decision reversing the ruling of Judge Field. The substance of this decision is perhaps the point to be brought out in this paper, and I would like to quote a few of the paragraphs which seem of interest:

"The fundamental question in the case is, what were the rights and obligations of the respective parties under this section? An important part of the chapter relates to the powers and duties of the Town in managing the business of furnishing water, in case it should purchase the property and franchise of the petitioner; and the intention of the Legislature to give the Town the right to take this business in charge is manifest. The authority conferred was not the power to take property by an exercise of the 'right of eminent domain,' but it was somewhat analogous to it. It was an authority to the Town to determine absolutely by its own act, in the form of a two-thirds vote, at any time during the continuance of the charter, that the petitioner's property and franchise should become its own. The statute calls it 'a right to purchase' and seems to contemplate a transfer of title in the form of a sale, and the execution of some proper instrument as evidence of the transfer. For, if the Town should vote to purchase, after the petitioner's works had been constructed, there might be a great variety of property, real and personal, to be transferred, and no way is pointed out, in which the Town could obtain and preserve in convenient form the evidence of its title except through an instrument of sale.

"But, as a preliminary to fixing the rights of both parties, — of one to have the franchise and property, and the other to have the pay for it, — no writing and no negotiation was required; nothing but the vote of the Town declaring its determination. The Legislature conferred upon the Company the corporate franchise, with a condition annexed in favor of the Town. By accepting its charter, the corporation impliedly agreed to sell whenever the Town by vote should decide to buy. The legal relation of the parties was as if the corporation had made in writing a continuing offer to sell, at a price to be subsequently agreed upon by the parties, and in default of agreement to be fixed by commissioners.

"The vote of the Town to buy was an acceptance of the offer which completed the contract. The rights of the parties were then the same as if both had signed an executory contract binding one to sell and the other to buy, at a price to be agreed upon between them, or determined under the statute. Neither party could then defeat the right of the other to have the contract executed. By the terms of the statute, it was to be specifically performed. The Town might, if it had chosen, have declined to avail itself of the offer held out to it, under this statute, to purchase at a price to be afterwards fixed, and have voted under the authority of Pub. Stat. Chap. 27, sect. 27, and perhaps of this statute also, to negotiate with the corporation in reference to making a purchase if a satisfactory price could be agreed upon. It was plainly an exercise of the Town's legal right to buy at a price to be subsequently fixed."

"It is argued that the petitioner entered into a contract with Wheeler & Parks which prevented the vote from taking effect, but this argument is not well founded. The corporation might go on under its charter and make any proper contracts for the construction of its works and for conducting its business. No contract that it might make could deprive the Town of the right to purchase its property and franchise under the statute, or prevent the appointment of commissioners to determine the price to be paid. Any contract in terms inconsistent with the exercise of that right would be contrary to the statute, and void as against the Town. Any contract properly made in carrying on its business would be binding upon it. Section 9 of this charter authorized a mortgage of its franchise and property under certain limitations, but it does not appear that the mortgage named in the vote of September 15, 1888, and stipulated for in the contract of October 30, 1886, was ever made. The respondent contends that the corporation was never so organized as to be capable of selling its franchise or property, or of maintaining this petition. It must be remembered that this is a corporation created by a charter, and that neither payment for its capital stock, nor even subscription for all of it by individuals was a necessary preliminary to organization or to the transaction of business by it.

"The provisions of Pub. Stat. Chap. 105, Sect. 9, in relation to organization are merely directory, and are intended to secure to all members of a corporation their right to participate in its proceedings. If all the members consent to an organization which disregards the statute requirements as to notice, the organization is valid. Newcomb v. Reed, 12 Allen, 362; Walworth v. Brackett, 98 Mass. 98. The proof of the Act of Incorporation, of the action under it and of the dealings of the respondent with the petitioner, as such corporation, is presumptive evidence that the corporation was legally organized, and is sufficient for the maintenance of a petition in the corporate name. Bank v. Silk Co., 3 Mass. 282; Society v. Davis, Id. 133; Institution v. Harding, 11 Cush. 285; Insurance Co. v. Jesser, 5 Allen 448; Toppings v. Bickford, 4 Allen 120; Hawes v. Petroleum Co., 101

Mass. 385. The neglect of the Town to act upon the report of its committee containing the offer of the petitioner shows that the parties were unable to agree upon the compensation to be paid. Indeed, bringing this petition without evidence of negotiation, or attempts to negotiate, would be enough to satisfy the requirements of the statute in regard to that. Burt v. Brigham, 117 Mass. 307; Aetna Mills v. Waltham, 128 Mass. 422.

"Upon facts agreed, we think the allegations of the petition are established, and that commissioners should be appointed to determine the compensation to be paid by the respondent for the franchise and property of the petitioner. Ordered accordingly."

Following this decision, three commissioners were appointed, Judge John Powell, Darwin E. Ware and Moses Williams, Jr. The firm of local contractors who had built part of the Town works from Great Pond, brought claim against the Town for the work done and for anticipated profits, which was eventually settled by the Town.

As the filter gallery of the company's plant was close to the shore of Little Pond, the proprietors of mills on Monatiquot River petitioned the Supreme Court for an injunction to restrain the Braintree Water Supply Co. from taking the water of Little Pond. There were many interesting points brought up in the ruling of Judge Devens, of which the following contain the substance:

"The plaintiffs have used, under this authority, Little Pond as a reservoir, maintaining a dam at its outlet, where they own a parcel of land, whereby the water is retained until they have need of, and have occasion to draw off the same for the use of their mills, about six weeks in the year. The water is of great importance to them. If deprived of it, it may be necessary to stop some of their mills during a portion of the summer, and its diminution would seriously injure them all. Before the shore of Little Pond and near it, the defendant has constructed and maintains a filter gallery, from which it draws water with which it supplies its customers, and it is found that a substantial part, much more than half of the water in the gallery, filters from the pond, and that all, or nearly all, of the remainder would have reached the pond if not intercepted by the gallery. The use of the water during the past season by the defendants diminished the quantity in use for the mills. It also appears that if the amount of water used by the defendants is increased a larger proportion will come from the pond than from the land side, and the larger the amount of water used the greater will be this proportion. It is the contention of the defendant that the word 'springs' and 'waters connected therewith' are sufficiently comprehensive to include this pond, and that the act gave the right to take any water in the Town of Braintree, with the exception of Monatiquot Springs, which are not within the watershed of Little Pond, leaving to the plaintiffs a statutory right to compensation therefor, if they are entitled to any.

"But a pond is quite distinguishable from the various sources of supply, whether those are the surface waters, or brooks, or springs which create and maintain it. When so large as to have become what is known as a great pond it is subject to all the rights which the public possess or which the Legislature may be entitled to grant therein. The fact that the Act, under which the defendant claims, specifies Great Pond, so-called, as one which may be taken, strongly indicates that the right to take other ponds of that

class was not inferred. 'Springs' as the word is generally used, means the sources of supply issuing from the earth as found therein by digging or otherwise opening it, and 'the waters connected therewith' are those flowing therefrom or bubbling up therewith.

"While in Peck v. Clark, 142 Mass. 446, it was held that a stream of water, whose sources were on the adjoining land, might pass as a spring, it was so because the evidence showed that this was what the parties had sought to describe, and that the word had been used by them with reference thereto.

"If the water cannot be taken directly from Little Pond, it cannot be drawn therefrom by percolation. Hart v. Jamaica Aqueduct Corporation, 133 Mass. 488.

"The process by which the defendant obtains it is unimportant, and the method is one well-known and often found convenient. It has often been held to be as complete a taking of water as the withdrawal of it by pipes. Brookline v. McIntosh, 133 Mass. 215; Cowbroy v. Woodman, 130 Mass. 410.

"The filter gallery, as described, is not intended to gather alone the water naturally upon or belonging to the land where it is, but being located on the shore the waters of the pond percolate through the intervening earth and fill it. Nor does the fact that the defendant has purchased the land bounding upon the pond, authorize it to withdraw the waters thereof for their purposes as a corporation. Potter v. Howe, 141 Mass. 357.

"The plaintiff claims not only the right to the entire waters of the pond, but to those within its watershed, and urges that the proper construction of defendant's charter does not authorize it to construct any well or gallery which would intercept any water which otherwise would reach the pond, and that the defendant's right to take any springs is thus limited to those which are outside the watershed of this pond. This would be to construe defendant's charter too narrowly. The corporation is created for an important public purpose. It is authorized to 'take the waters of any springs or artesian or driven wells within the Town of Braintree', etc. The reason why we hold that this does not authorize the taking of the waters of Little Pond is, that the water thus collected is known by a different description from the waters which are its sources of supply, but it is contemplated that these may be taken. It is the right of each land owner to dig wells on his own premises, even if he thereby intercepts the flow of water to the neighbor's well or streams. Greenleaf v. Francis, 18 Pick. 117; Chase v. Silverstone, 62 Maine, 172.

"If all that the defendant had done was to construct a gallery which would reach the underground sources of supply alone, which were on the land when it was constructed, or even the surface water which might flow thereon, quite a different case would be presented from that which is here found. When the defendant constructed a gallery, the principal use of which was to take water from the pond, which it had no right to do, even if it thereby obtained some water which it might lawfully have appropriated, it had not fairly exercised the authority with which it was intrusted, and independent of any right which it might have to take the springs, the plaintiffs could fairly ask that it be enjoined from maintaining it. If the defendant has no right to take the waters of Little Pond, it is necessary to inquire whether the plaintiffs have any such right therein that they may ask protection of the Court in the enjoyment thereof, as against the defendant who is supplying water to certain inhabitants for domestic uses, and it is the contention of the defendant that the plaintiffs had a most revocable license to use and

enjoy certain public property which the State might terminate at any time at its pleasure." Wattuppa Reservoir Company v. Fall River, 147 Mass. 548.

"The plaintiffs have directly maintained that their dams have had the exclusive control and use of the waters of this pond for sixty-five years; have erected valuable mills which have been of incidental benefit to the community, and have had the advantage, during that time, of the water for their mills. Without considering whether this, under all the circumstances, would give more or greater rights, it is sufficient at least to entitle them to the enjoyment thereof as against a corporation acting *ultra vires* in removing its water. Nor is it any answer to say that defendant is doing a valuable public work in supplying the citizens of Braintree with this water. This right to take the water lawfully collected and enjoyed by others is still limited to that which is conferred by its charter."

. . . . .

"Upon the whole case we are of opinion that the plaintiff was entitled to an injunction forbidding the defendant withdrawing the water from Little Pond, and from using the gallery constructed by them, unless it can be so altered that it may be used without producing this result."

The company made final settlement with the mill owners for $20 500.

On March 13, 1891, the commissioners fixed the amount to be paid from the Town of Braintree to the Braintree Water Supply Company as $159 610.44.

I am pleased to mention that the Hon. James T. Stevens, who so faithfully represented the Town through much of the troublesome time of acquiring the water works, has been since 1902, and is to-day, a member of this Association. He has continued since the construction of the works as chairman of the Board of Commissioners, and has just passed his 83rd birthday. While somewhat physically infirm, he is still at the height of his mental capacity, an alert, powerful, courteous gentleman of remarkable ability. He is one of the wonderful men who have brought out the best in municipal management with a long record of successful and businesslike water-works operations.

The principal in the Braintree Water Supply Company was Mr. William Wheeler, a member of this Association since 1889, and one of the most distinguished water supply engineers in the country.

I wish to especially thank the last two mentioned gentlemen for their assistance in furnishing me information, records, etc. in getting together this brief description of the purchase of these works.

SHOULD THE WATER DEPARTMENT BE MERGED WITH OTHER MUNICIPAL DEPARTMENTS IN ITS MANAGEMENT AND FINANCES?

BY GEORGE A. KING.*

[*Read September 13, 1922.*]

Our late esteemed member, Frederick P. Stearns, said:

"I believe if any city had a system by which the public works could be wisely, prudently and honestly ordered, constructed and maintained, it would nearly have solved for itself the vexed problem of municipal government.

"It is self-evident that no system will insure complete success in the management of public works so long as it is possible to place incompetent and dishonest men in charge; but it is also true that the character of the men selected and the efficiency of their work depends very much upon the system employed, and the adoption of a good system is therefore a long step toward good government."

It is not to be expected that one man can be master of all the branches of engineering in the public works of a city, but by a division of the work it is possible to have a competent man at the head of each department and he will be able to give its problems the attention and study they need and this man should have executive control of his department to gain the highest efficiency and responsibility.

The size of the city may determine how this shall be attained, whether by a man at the head of all the executive departments with assistants in charge of each, or by separate heads for each department who shall co-operate where their common interests meet, regardless of the size of the city. The water supply which involves the health, happiness and protection of the community should receive the best and most disinterested consideration of the authorities. Consideration of economy is necessary but it loses its force and argument when opposed to the health and comfort of the people. There can be no financial measure of questions relating to the public health.

The management of a water department calls for a man of wide and varied experience. I cannot express it better than to quote from Hubbard and Kiersted on "Water Works Management and Maintenance":

"The maintenance and operation of a system of water works is often believed to be a purely business proposition requiring essentially a business management. Regarded in a broad and comprehensive sense this view may be correct, for a far-seeing business management would not over-

*Superintendent Taunton Water Works, Taunton, Mass.

look the purely technical or scientific considerations which are necessarily involved in the management of a modern water-works system. The questions involved do not relate solely to the sale of a commodity supplied in the form of a water service, but also deal with the quality of the water supplied and the design, construction and operation of the physical property by and through which the service is rendered.

"The selection of a water supply drawn from an unpolluted source is highly desirable and inspires the confidence of the public in the management of water works. This confidence, however, may be also secured when circumstances compel the use of a water drawn from polluted sources, provided the water be properly purified before use.

"Taking into consideration the many things which have to be regarded in the selection and purification of water supplies, it is clear that science can be serviceable to a water-works management in many ways, and the advantage of this kind of service should become more and more apparent as communities increase and prosper. If the aid of science is necessary to select a source of supply free from dangerous pollution or to detect the presence of unobserved polluting influences, its aid is even more necessary in those cases where a source of supply, known to be polluted, requires thorough purification. It will not suffice to seek scientific assistance in such a case solely for the purpose of designing and constructing purification works, but it should also be retained for the purpose of insuring the satisfactory operation of these works and the preservation of the purity of the water after treatment. The safeguards of the public health in the way of constructed works need guardsmen to see that such works positively perform the functions expected of them at all times — a service which may yet have to be supplied through the State or Federal government.

"To the requirements that extensions of, or additions to, a system of water works be made in accordance with good engineering practice, that the efficiency of a system from a mechanical standpoint and the sanitary quality of the supply be maintained or improved, should be added the requirement that the department be operated on a business basis."

Mr. Darling, in a paper before this association some years ago, said: "The superintendent should be a man whose *whole mind* is devoted to the work, but it does not follow that he must be able to affix C. E. to his signature, provided the services of one can be obtained at his convenience or his need." Ex-Mayor John O. Hall of Quincy later stated that no department contained more perplexing problems than the water department.

September, 1911, W. H. Richards of New London read a paper before this association in which he gave some of the qualifications necessary for a person in charge of a water supply and said that — "He should be an engineer in the larger sense, he should be ingenious, with a thorough knowledge of construction and tools, he must have, or immediately acquire, knowledge of the fundamental principles of hydraulics and above all understand the principles of business management — and with all these he has much to learn as the management of a water works requires special knowledge and he should have a logical mind to separate the theoretical from the practical."

I do not believe we are egotistic in making all these claims for our department and the qualifications we should possess. Can we expect to

find a man who will give to the water department what we believe it needs who also has on his mind the sewers, streets, parks, etc.? The public is more interested in its streets and parks and more insistent that these receive attention than in the water department which controls that which is much more essential to its health and happiness, and all thinking people must concede that it is the most important of all.

With the water department united with the others it will not receive the attention its importance demands. With the call for many other qualifications those specially needed in a water department will be overlooked. We all probably realize that the more closely we are in touch with problems and conditions the more important they seem to us and the more likely they are to receive the attention they deserve. Dr. Brown said a great many years ago that "the health of a city depends more on its water than all the rest of its eatables and drinkables put together."

The supplying of water to a municipality is not one of the original functions of town government. It is one of the necessities occasioned by our advance in civilization, the demand for which has been met by legislative enactment under the general provision that the legislature may grant what is necessary for the welfare and health of the community. It is a form of public trading, better known as a public utility, which the municipality has been allowed to finance principally for the preservation of public health and incidentally for fire protection and manufacturing purposes but not for the purpose of making a profit. As a public utility it should be managed independently of the general functions of municipal operations.

This argument for separate management applies also to the financing of the department. The paper of Mr. Hall, previously mentioned, states that "transfers of water receipts to various foreign departments of the public service are violations of law and of great injustice to water takers. Water expenses should be paid by takers and any excess of revenue over expenses should be returned to them in the form of reduce rates." Those who remember Mr. Hall will agree with me that he was a clear thinker and sound reasoner.

While it may not be quite pertinent to this question I will quote a little further from him. He says that the "expense of establishment of water should be borne by real and personal property of the community and should appear in the general tax." I do not agree with him wholly as I think that the interest on the debt incurred in construction should be paid by the consumer of water. Mr. Hazen and many others hold that the rates should also include a sum for depreciation which, of course, is good business and so recognized by public utility commissions.

In Massachusetts, the acts authorizing the establishment of municipal water supplies designate the methods of financing and there is a great lack of uniformity. Where the Director of Accounts, or his predecessor, has been called in for auditing and establishing a system of municipal

bookkeeping, he has recommended an appropriation for the use of the water department, the same as is done in the usual municipal departments and the receipts are turned into the general fund of the treasury, to be used as are the receipts from taxes.

In case of municipally owned lighting plants the statute (Sec.58, Chap. 164, General Laws) requires the rates to include "all operating expenses, interest on the outstanding debt, the requirements of the serial debt or the sinking fund established to meet such bonds, and also depreciation of the plant reckoned as provided in the preceding section, and losses." The depreciation referred to is 3 per cent. of the cost of the plant, "exclusive of land and any water power appurtenant thereto." The manager or municipal light board has sole power to draw on the treasurer for expenses of the department for the funds earned and additional amounts appropriated, if any. The Public Utility Commissions of Massachusetts, Wisconsin, and other states seem to be in accord on this method of accounting.

Why there should be this anomaly in the management of two municipally owned public utilities so closely related is difficult of explanation. While we may deprecate further state control, it is much better to be controlled by a commission who are experts in the management of utilities than by a board viewing the matter wholly from a bookkeeping point of view. Massachusetts General Laws, Chap. 44, Sec. 36 & 38, authorize the director of accounts to establish accounting systems on petition of town and city authorities and these accounting systems shall be such as will, in the judgment of the director, "be most effective in securing uniformity of classification in the accounts of such cities, towns and districts." You notice that the system is wholly for the purpose of securing "uniformity of classification." I think that the methods of accounting, required by the public utility commission, are more efficient and businesslike than those recommended by the Director of Accounts.

Ten years ago Morris Knowles advocated state control and quoted from Hon. John H. Roemer, Chairman of the Railroad Commission of Wisconsin, as follows: "No greater benefit has been bestowed upon the public by regulation of public utilities than that resulting from the operation of the law upon municipal public utilities. . . . . . As a matter of fact, regulation is more necessary with a municipally owned plant than a private one; because people often endure service and rates imposed upon them by their own town officers which will call forth vehement protest if a private company were involved."

My belief is that the system under which the municipal light plants in Massachusetts are managed and financed is the best which has been devised for public utilities and that cities should adopt a similar plan for their water departments. It is not necessary to put them under state control to adopt this system and a general adoption of the system might forestall state control.

Discussion.

President Barbour. This is a live subject, concerning which we have heard a great deal of talk by the various superintendents during the past few years. It ought to lead to discussion. It involves the question of subordinating the Water Department to a Board of Public Works, and of diverting the income of the Department to the general treasury of the city or town. It is a question whether under such conditions the morale of the Department can be maintained as well as under the old system, where a man was in direct charge of the Water Department and was credited with the results. I hope that there will be discussion.

Mr. Albert L. Sawyer.* The Haverhill Water Department is one of those that has been entirely unmerged in all the course of its existence, and it has worked pretty well there. I think there are very few of the citizens of Haverhill who would willingly acquiesce to its being merged with the other departments of the city. The city took the works about thirty-one years ago, and the Act under which they took them provided that it should be kept entirely separate. It seems to me you get a continuity of policy in that way that you can't get if you are mixed up with politics and have the aldermen and councilmen deciding what the men shall do and what you should assign them.

In the first place, in Haverhill, what little money we have had has always gone into the development of the works, or into a reduction of the water rates. If we have a surplus it does not go into the municipal funds. Take the average city government, for instance. You have perhaps the Mayor or Chairman of the Board of Aldermen on the Water Board, ex-officio, and if they outline the policy at all, the longest they would probably be on the Board would be four years, and then you get a new set in and the policy changes. In Haverhill in the thirty years since 1891, we have only had seventeen Water Commissioners. One died in 1918 who had served twenty-seven years. We have another man on now who was appointed in 1894, who has served twenty-nine years; another who was appointed in 1899, who has served twenty-two years; and two other members have served eleven and ten years respectively. In that way they start out with a policy of what they want to do and they keep pretty well to it.

We used to say in Haverhill that we could generally trace out the residence of a councilman or alderman by the lamp posts in front of his house, and the edgestone on the street where he lived. I do not mean to say but that the Board of Water Commissioners are susceptible to those who howl the loudest for water, but they have tried to treat all applicants fairly. Haverhill extends over a great deal of territory, and now about everybody who has a farm out in the suburbs expects to have the mains extended.

The policy of the Water Board is like this: Those in need of water ser-

* Water Registrar, Haverhill, Mass.

vice who live along the highways seem equally deserving, and they usually endeavor to do a proportionate share of extension work along all lines each year until the work is completed. In other words, they try to treat all people alike who want an extension of the water mains and give each one fair consideration.

I have a letter here which I was showing to a water-works engineer to-day, and he thought it was possibly of interest to the members of this Association. It is a letter I received in 1908 from William H. Moody. Mr. Moody was, as probably most of you know, a lawyer in Haverhill, a member of Congress, Secretary of the Navy under Roosevelt, Attorney General, and then appointed to the Supreme Court of the United States. He was the counsel, in connection with ex-Governor Robinson, for the city at the time we took the works In connection with a paper which I read before the Association in 1908, I wrote him and his letter in reply was as follows— I am going to read it to you because it seems pretty good common sense:

SUPREME COURT OF THE UNITED STATES,
WASHINGTON, D.C.

ALBERT L. SAWYER, ESQ. April 10, 1908.
HAVERHILL, MASS.

My dear Mr. Sawyer: —

I hope you will excuse the delay in answering your letter of the 30th ult. I have been looking at the different acts relating to the Haverhill water supply and trying to recall the circumstances of their passage.

I might, with the aid of memoranda which I have at home, state the facts with greater accuracy than I can here. I am so anxious not to tell you anything of which I am not sure that I fear I can say little worth saying.

Of course I prepared the Act of 1891. So far as that act dealt with the scheme of management of the aqueduct property after it should be acquired by the City, it, I think, passed the Legislature as I prepared it. I do not think the Act is quite like any other but I must speak with caution on this point. This much I know; the main purpose which I desired to accomplish, carrying out in this respect the wishes of Mayor Burnham and the leading members of the very able City Council then in office, was to separate completely the Water Department from all other affairs of the City. It was hoped thus that the Department would be managed upon strictly business principles without regard to politics. To that end it was provided that the Water Commissioners should be appointed for a term of five years, that only one should be appointed each year, and that the City be left to pay for the water which it used like any other consumer. The power of management of the Department was vested exclusively in the Commissioners subject to removal by the City Council for cause.

I drew the Act of 1892 (Ch. 417) and put into it the provision that any land taken for the protection of the water supply might "be managed, improved and controlled by the Board of Water Commissioners in such manner as they should deem for the best interests of said City." The purpose of this provision was to enable the land thus taken to be used for the purposes of a public park as it since has been. I hoped for good results from this provision but I did not realize that the result would be a most beautiful park in which all our people may justly delight.

I drew the Act of 1896 according to my best memory. The purposes which it is intended to accomplish appear sufficiently from the Act.

I believe that this is all that I can say now which by any chance could be of service to you. Very sincerely yours,

(Signed) W. H. MOODY.

Now, we started out along these lines, and, as I say, it has worked very successfully. The Water Department has been entirely removed from politics. The only connection, in fact, that we have with the Municipal Council, is the appointment of the Water Commissioner each year and the auditing of our accounts by the City Auditor. Outside of that, of course if the Council makes recommendations of certain things, the Board would carefully consider them. But we have never been interfered with, and I do not think many of the citizens of Haverhill would advocate merging with other departments of the City.*

I might say, as a shining example of keeping out of politics, that last May I completed thirty years' service in the Water Department of Haverhill, and I presume if it had been in politics I would have been fired years ago.

MR. A. R. HATHAWAY † (*by letter*). Pardon me for following you to New Bedford by letter (for that is the only way I can follow you), but I was just looking over the program and note you are down for the question "Should the Water Department be Merged with other Municipal Departments in its Management and Finances?" and I wish I might be there to hear your paper and to add my little say against any such merging.

But you know that in such matters the man that has had over forty years' experience and observation is not as well qualified to pass on such questions as is the young "expert" (so-called) from the modern Bureaus of Research, and the charter agitators of the present day.

However, if there should be opportunity to be recorded on the proposition I wish you would put me down with an emphatic "No."

You and I know that every water works, *municipally owned and operated*, is all the time bucking between two influences; that of the honest and conscientious water official for an up-to-date *business adminstration* of its affairs, and the beneath-the-surface (often above the surface) influence of the politicians and their followers for a *political administration;* with the chances that the latter will sooner or later control, when the water works will lose its natural standing of a public utility.

I think every *thinking* citizen will admit that a water works, like gas and electric works, street railways, telephone systems, naturally belong to the *public utility class*, and in former years were more largely owned and operated by private corporations instead of municipal; that such private corporations, in order to obtain the best results, adopted all modern practices and devices and are controlled in every state by some form of of Public Utility Commission, which protects both the corporation and

---

* Our water act provides that the Water Commissioners shall fix the price or rent for water supplied annually; and the income received therefrom after deducting all expenses and charges of distribution shall be applied, — first to pay the interest on bonds issued; second to pay the sinking fund requirements for loans; third to the payment of all current expenses; fourth the balance if any, may be applied to the sinking funds at the discretion of the Commissioners. The Commissioners may expend from the annual receipts for the purpose of new construction, a sum not exceeding twenty thousand dollars in any one year. Our officers are not in City Hall but in a separate building leased by the Water Board, and we handle all receipts and expenditures

† Water Registrar, Springfield, Mass.

the people served, and that they thus can be operated for good service and also to the payment of dividends to their owners, the stockholders. And I maintain that a change to municipal ownership does not, or should not, alter the fundamental status of such water works or its relation to the public served; that the fundamental practices of best operation under a private ownership should certainly be followed under a municipal ownership, in order that the fullest measure of public service and the best financial results may be obtained. The only way to insure these results, to my mind, is to treat such municipal water works (not as one of the governmental departments of the municipality, which are supported by tax levy, but) as an independent investment of the city, to be self-supporting and operated on purely business and public utility lines. The more it can be divorced from other departments and political control, the better operating results you will reach in the long run.

Without legal authority perhaps, we are trying to educate our citizens away from the "department" idea by placing on our stationary and bills, etc, the words "Municipal Water Works" instead, as shown at top of our letter sheet.

MR. PATRICK GEAR.* Considering criticism of the man that is doing more for the Water Departments of New England and Massachusetts than any man that I know of, or ever heard of, and hear the criticisms that he has to stand from those who don't know the business that he is attending to for the people of the State, look around and see what other Departments do to defend the people and promote their interests. When the Commissioner of The Massachusetts State Board of Education advocates anything every superintendent in this State is back of him to help him out; when the State Department of Public Health tells us how the water is to be taken care of in the State, we put our hands in our pockets and let the director fight it alone; and when different cities and towns take it into their heads that they will bring the water and the fire and the streets all under one man, I get a little hot. If you make that man the king-pin of the city, the Water Department will be bled to help out the Highway Department, and in a few years you will find that the Water Department has not got anything to put out a fire. I know of some cities where they change the Water Commissioners every time they change the Mayor, and they change the Mayor every time they have a chance to elect a new one. In a dry summer or a cold winter, they have to buy water from their neighbors. I believe that there is only one right way, and that is to let the Water Department have their funds and not come to them every time they have a little money in hand that they do not want to use right away. Let them put it into their plant, and if they have not a chance to put it underground they can put it on top of the ground where it can be seen, so that everybody will realize they are doing fine work. All our good work is buried. It is difficult sometimes to make people believe that we are doing good work, until a fire occurs.

*Superintendent Water Works, Holyoke, Mass.

I think the Water Departments of the State should stand back of the State Department of Health in everything they do, and if they find a city that wants to merge the Water Department with the other Departments, go to the State House and fight it out and say, " We shall not let you do it." But if you let them bleed the Water Department, tax you for it, put it into the streets, build up a Fire Department, build up a fine park system at the expense of the Water Department, it will be poor economy in the end. There is a fine city in our part of the State that takes $30 000 or $40 000 a year out of the Water Department and puts it into the other departments. That is not right. But do not reduce the rates too low. They are not high in this section of the country. In Holyoke the money is kept in the department.

MR. CHARLES W. SHERMAN.* I am inclined to think that there is, perhaps, greater danger to the smaller cities and town than to the larger ones. The development of a plan combining all the public works of a municipality is not so dangerous to the larger community in which each department is of such magnitude that a man of considerable ability is necessarily employed in charge of it.

In the smaller cities and towns, on the other hand, everything may be put in the hands of a man who can't be a specialist in all lines, with the result that the man in charge of another department than the one in which he is particularly interested is practically only a foreman under him, with no great authority and with no prestige behind him, and the department of which he is in charge suffers in consequence.

I was considerably impressed by Mr. King's argument in favor of proper accounting for the Water Departments, and recommending for our consideration the form of accounting recommended by the Utility Commission for Electric Light Plants. Perhaps many of our members are not familiar with the fact that in Maine all Water Departments, whether publicly or privately owned, come under the Utility Commission. The Public Water Departments have to make exactly the same returns to the State Utility Commission that the private water companies do, in Maine, and I believe it has been a mighty good thing for them. The smaller water departments in too many cases, especially country places, have no accounting system worthy of the name, and the Maine Utility Commission, which has now been doing business along this line for about eight years, has done wonders in putting those things on a more scientific basis. Of course the older companies which did not have much of any records to start with — I hate to use the term, but I must say that they had to " fake " some to start with, and perhaps what they used as basic figures are not above suspicion. But the figures which are being added annually do really mean something. I think other states might well follow Maine to that extent, by putting the accounting of the Water Works of a publicly owned utility on exactly the same basis as a privately owned one.

*Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

Mr. Henry A. Symonds.* About 1914 a bill was entered in the Massachusetts Legislature to put the water companies of Massachusetts, which had been up to that time under no special regulation, under the, Gas and Electric Light Board. It seemed at that time to the water companies that this was going to entail a great deal of extra work, that it was something which the companies would not get much real benefit from, and that there was going to be a large expense involved. The result was that when the bill was entered, the first year, I think there was almost unanimous opposition from the water companies. The bill was again entered the next year, not much opposition developed, and it passed and became operative in 1915. I think the first year the companies did the work rather grudgingly. Of course a great deal of work was involved in getting things straightened out along the lines required, and there was considerable complaint from the water companies all over the state. The second year, as things had been somewhat organized and the information collected, the companies did not find as much fault, and I think about the third year they commenced to rather like the idea. It became easier, and we found we were getting a great deal of benefit out of those reports, and out of keeping the systematic accounting and complete records of the physical plant. That has come to-day, I think, to be recognized as having been an excellent move not only for the general public but for the public utility companies themselves, and really a much greater benefit for the public utilities than for the general public.

Mr. Sherman has just mentioned that the State of Maine Water Departments have been placed under public control. I think Connecticut is also under a similar regulation. In Connecticut, and I presume the same is true in Maine, and perhaps in other places, the report of the physical plant is being required along the same lines as is required of the private water companies. That is something which, to those who are looking for general information, general data relative to development work and the operation of the plants, is of very great value. The simple, uniform accounting is a step in advance but, added to that, the uniform statement of the operation of the plant, from not only the companies but from all municipal plants, would be of very great benefit when made accessible to all operators. It would be one of the best things which Massachusetts, and the other states which have not taken it up, could do, — to place these plants, whether publicly or privately owned, under Public control and establish a standard basis not only of accounting but of all operating records.

Mr. King. Some weeks ago I wrote to Mr. Whitney of Newton asking some questions about their system, and last Monday I received this reply:

---

* Consulting Engineer, Boston, Mass.

CITY OF NEWTON, MASSACHUSETTS.
CITY HALL,
WEST NEWTON.

MR. GEO. A. KING,
Supt. Water Works,
TAUNTON, MASS.

September 9, 1922.

My dear Sir, —

The Charter of the City of Newton provides "The Water Department to be under the charge of the Water Commissioner who shall have charge of the construction, alteration, repair, maintenance, care and management of the Water Works."

There is no "Board of Public Works" expressed or implied in our Charter or Ordinances, though the Mayor as the Executive head of the City can, if he so chooses, assume such management.

However, to a very fair degree coöperation between Newton departments exists with but few cases of overlapping or interference with each other. Men capable of managing more than one department are few in number and corporations secure most of these.

Consolidation of an income-producing Water Works with other departments "lean and hungry," results at times in the absorption of any surplus income by others and obliges the Water Works to almost go on their knees for sufficient funds to keep their plant in reasonably good condition. It is sound finance to use Water Income for Water Department purposes only, and I believe the average citizen gets more satisfaction in dealing with a Water Works than with a small division of a Public Works Department.

Very truly,

(Signed) J. C. WHITNEY,
Water Commissioner.

MR. M. N. BAKER.* A phase of this subject that does not seem to have been touched upon is that one of the great difficulties in the smaller places is to get a really trained and experienced man to handle the separate departments. It is often quite beyond the financial possibilities, or is thought to be so. If, to use a familiar expression, we say that the City Manager form of government is adopted for these smaller places, you at least have a man who is trained in municipal administration to run all of the departments.

It is because municipal government of late has been taken up from the viewpoint of the city as a whole instead of being split up into many and largely independent departments, that there has been this tendency to consolidation.

New England is accustomed to Water Boards, and looks upon them with favor because they have been largely continuing bodies. But looking at the subject from a country-wide viewpoint, we find quite different conditions prevailing elsewhere.

We have to-day in the whole country doubtless 500 to 600 cities that have the Commission form of city government, whether with or without City Managers. It is the change to the Commission plan of government which has brought about in a large number of cases changes that have affected the several departments. We need better city government and

* Associate Editor *Engineering News-Record.*

we must look at the city as a whole instead of at each separate department, and where there is a Water Board and a Sewer Board and a Light Board, as they still have in some places, and used to have in many, independent of each other and of the City Council, haphazard system of government is the rule, and it is impossible to have that unified control and central responsibility that is essential for efficiency and economy of municipal administration.

The basic thing is to see that in the management of the water and all other departments, scientific principles of control are established and enforced to make sure that the Water Department, as has been suggested, stands on its own bottom, with water rates fixed to provide properly for operation and maintenance and take care of capital, and to ensure that the Water Department revenues are not robbed, as they have been in many cities, to pay the expenses of other departments.

Finally, the single-headed Commissioner is now generally considered by careful students of municipal and state government to be far preferable to the Board of Commissioners for the exercise of executive functions.

Mr. Gear. Regarding this commission form of government. Of course the agitation was started by a class of people who think they can reform human nature. They will have an awful job.

Our Water Department has always been kept separate from any other municipal department. There is no reason in the world why one man should govern two departments. If one department is getting an income, the other departments are trying to spend it. One Board should never cover the two. The old system of government that we have had for hundreds of years is fairly successful, and the new forms just a fad.

I have not seen any improvement under city managers. Some of the cities that had them have gone back to the old system.

Mr. David A. Heffernan.* Up to 1902 we were a private water company, having a Board of Directors of course, and a President who took a very great interest in the equipment of the plant. Plans were formulated to use certain types of gates and hydrants, and run on the principle of uniformity. After all the time that I have been in the employ of the Town of Milton, thirty-two years, I was wondering, if I retired tomorrow, what would happen to the present equipment. Uniformity of gates, hydrants and other equipment standard in all ways, opening to the right, and giving perfect satisfaction. The result in changing over to a town manager, or to a Commissioner of Public Works would be that probably the whole system would be revised by a man coming in with different ideas, thinking that the equipment of the plant is passé. I will admit that there are other equipments as good as mine, but when you get a thirty-two-year-old system, with thirty-two years of service, and still going and giving satisfaction, I think it is creditable.

* Superintendent Water Works, Milton, Mass.

To-day we have committees on Standardization. For what purpose? Just for the very purpose we are talking of to-day, because of the changes in government through politics and the like. Different Commissions being elected, different materials, different types being introduced into that system, result in not knowing what you have there; you have special threads — you don't know what they are. I am on a Committee on Standardization of Brass Fittings. We have been on that for three years, not having made much headway, and I am afraid we will not make much, for the reason that there are certain fixtures on the market which control practically 75 per cent. of the Water Departments. They have special threads. The manufacturers even go so far as to say that the standard thread is passé. I can show you an advertisement in *Fire and Water* stating that the standard thread to-day is passé. Just think of it!

MR. R. J. THOMAS.* The motive behind Mr. King's paper probably may not be understood by a number of the water-works people here. That is to say, they do not realize the tendency that is prevailing in Massachusetts to-day, and in probably some of the other New England States, to abolish the Water Department as a separate department, and place it under a Board of Public Works, simply making it a subordinate branch of the City Government, without a Superintendent. That tendency is growing, and probably several cities now with water works organization, will be merged under a Beard of Public Works within the next year or two. It is an evil tendency that is going to make for poor management of water works and we, especially the Massachusetts members of the New England Association, ought to organize to do what we can in opposition to it.

In regard to this discussion that has been brought up, by Messrs. Sherman and Symonds, of the State having some control and regulation of the publicly as well as the privately owned plants: That may be a remedy. But something has to be done to prevent the Water Works Departments from disappearing in many of our municipalities in Massachusetts. There are quite a few cities in New England that are not represented here to-day, because nobody connected with them is interested in water-works matters to the extent of coming to these meetings. About a year ago, I had a conversation with a man who was head of the public works department in one of our New England cities. I asked him why he did not attend the water-works meetings. He did not think it profited him to come. In that same city at one time lived a president of the New England Water Works Association, who was a very able president, and superintendent of water works, and he has left his impress on that city to-day. The water works as he designed and built it is furnishing not only that city but several neighboring towns with water. But his successor who also has other branches of the public work to take care of, thought it would not profit him to come to these meetings. I suggested to him that it might profit the Association if he came.

* Past President American and New England Water Works Associations.

It seems to me that this is a live question, especially because they are taking the revenues of the Water Department and using them for other purposes. I remember some years back, the Water department of the City of Fall River had $80 000 surplus. They wanted to put in a new standpipe, but the City Government appropriated the $80 000 for other municipal purposes. The mayor was friendly to the Water Department and he held it up until the Water Commissioners had time to act. Representatives of the Water Works Association went to the Legislature and had an Act passed. We supposed at the time it was going to be a general Act to prevent the taking of water-works revenues for any other than water-works purposes, and that it was going to apply to all cities, but as passed it simply applied to Fall River. It should have applied generally.

I know of a case where a member of the Legislature introduced a bill to reduce the rates in his city, for the sole purpose of making himself popular, that he might be elected Mayor. But he proved one of the worst Mayors they ever had. Reducing the water rates is popular in a great many places. The Board of Public Works could take care of that feature so that the rate will not be reduced unduly so as to promote the interests of any man who is seeking to be Mayor or any other public officer.

I think we ought to get this matter studied and see that there is a defense organized against these attacks on Water Works Managements in our cities and towns in Massachusetts or Rhode Island, or wherever it is necessary.

Mr. J. W. Diven.* The using of water-works funds, or any part of them, or the surplus, for general tax purposes, is certainly an inequitable form of taxation. It is not a tax based on the value of the property, because it is a tax on the users of a commodity. A manufacturer using a large amount of water is paying a tax way beyond the proper tax on the valuation of his property. Certainly a water-works fund, if they do create a surplus, should be used by the water department, possibly for retiring bonds or for depreciation. If they have not use for a surplus then they should not create a surplus. In other words, a municipal plant should base its rates on the actual needs. If the revenue is larger than is needed for the operation and proper maintenance of the plant, then reduce the rates. Certainly to use that money for other city purposes is taxing the commodity user instead of the value of the property.

Mr. Gear. We have done that a few times. We created a surplus of $40 000 and used it to extend a main five or six miles into a new territory. It could not be done with the surplus from one year.

A 24-in. pipe line 4 mi. long is proposed for next year. We are creating a surplus now, and have been for the last couple of years, to carry that out. We do not intend to borrow any money to do it. Some people think when you have a surplus one year it ought to be taken away from you.

* Secretary American Water Works Association.

Mr. Diven. You are creating a surplus for needs. I said, not to create a surplus in addition to needs. It is a question whether it is right and proper to use the surplus of the Department for construction work. By using your surplus you are taxing the large user of water, the large manufacturer, perhaps, to extend the mains. To my mind extensions should be made out of capital.

Mr. King. When I first began to study this subject which you assigned to me, I came up against the part which Mr. Baker referred to, — the difficulty of applying a system to a small municipality and to large cities like Boston, Worcester, New Bedford and Fall River. I could not see how I could say anything that would fit all those places, and so I had to write in a very general way. I think one great difficulty we meet with is the lack of appreciation of the benefits which people receive from the water system. Just an illustration: during the war time when we wanted coal, what rating were we given? About third class. We could have it after two or three other classes got it. I went to the Manager of our Coal Company and told him what they would lose if we could not pump water. He said, "I will see that you have coal; I did not realize your importance." I think that is the feeling all through, the people do not realize the importance of the Water Department, and when you consolidate with other Departments the other Departments are going to have the attention, almost exclusively, of the party who is put in charge, unless he happens to be a water-works man.

Mr. Sawyer touched on the continuity of purpose of the Water Boards. We have had in our 46 years, including the members we have now, eight Commissioners, — three at a time. I think that has given a continuity of purpose all these years, and that the City of Taunton has benefited by such service.

The President wants to know the good of all this talk unless we do something, and I would move that a committee be appointed from the Massachusetts members to consider the advisability of taking some action with the State authorities on this matter.

Mr. Diven. Why confine it to Massachusetts; why not the other states?

Mr. King. Years ago we had a matter come up in the Legislature and this Association voted to assist. A circular was put out and Mr. Kent signed it as one of the members. He was from Narragansett Pier. That was used against us, — that a man from Rhode Island should be trying to influence the Massachusetts Legislature. We have to watch all those things.

Mr. Michael F. Collins.* There is one point I want to bring up and I think it might be added to Mr. King's motion. A number of years ago this Association formed a committee to appear before the Massachusetts Legislature and have a measure passed that would make water taxes a lien on the property. Last year Mr. Sullivan of the Boston Finance Commission introduced a motion, and I believe it was passed by the Committee on

* Superintendent Water Works, Lawrence, Mass.

Cities and Towns, that the City of Boston should be authorized to have all their water assessments placed as a lien on the property. I have spoken to a number of men I know, and to a few members of the Legislature, to have them do what they could in order to have that measure passed. I told them at that time that the City of Lawrence was badly in arrears on water bills. In our city we have had a number of property brokers that have been passing the same piece of property over, sometimes two or three times a month, so that it is almost impossible for the Water Department to keep track of them, know who they are and from whom the money is coming That measure was introduced but was defeated by some of the property owners of the City of Boston, though the committee reported favorably. I believe at that time there were a million and some five or six hundred thousand dollars due the city of Boston for water assessments, and everybody thought under those conditions it would pass, but it did not.

Now, if such a bill could be embodied in the motion made by Mr. King, that this same committee take under consideration the advisability of bringing the bill before the next Legislature, I think with the coöperation of the City of Boston, and with the help and coöperation of all the Massachusetts Superintendents and their friends, that there would be no question of doubt but what that measure would go through. If it did go through so that money so owed on property would at the end of a year, if it was not paid, go on a tax bill, I think all the Water Departments of New England, and of Massachusetts especially, would be benefited by it.

Mr. Diven. My point was that other states might need it as much as Massachusetts.

Secretary Frank J. Gifford. Would it be wise, in view of the fact that you are trying to divorce the Water Department from other departments, to get a bill through which will relieve you by having the Tax Department collect your bills for you?

Mr. Collins. I do not think that would have any bearing on the subject at all.

Mr. Gifford. There might be a question whether you were looking for help from other departments, when you want to run your own department. You have the power of shut-off at any time.

Mr. Collins. But you have that after the property is sold, and you can't make the purchaser pay the back bills.

Mr. George F. Merrill.* That is a good suggestion. I think they should be entirely separated if we go to any State authorities for action.

President Barbour. I will now read Mr. King's motion as he has written it out: "It is moved that a Committee of Massachusetts members be appointed to consider the advisability of united action with State authorities of Massachusetts on the subject of merging the Water Departments with other Departments in management and finance, or either of them." (This motion was duly seconded and carried.)

* Superintendent Water Works, Greenfield, Mass.

WHY WE SHOULD INSPECT WATER-WORKS EQUIPMENT.

BY THOMAS E. LALLY.*

[*Read September 13, 1922.*]

The remarks I shall make in this paper I hope will be of interest to superintendents — and this paper is offered with that idea in view.

Superintendents are usually criticised when some part of the system fails. These failures are usually accompanied by a flood resulting in damage to basement property or damage caused by wash across property to lower elevations, and in most cases the newspapers have pictures of the flooded area and the heaved street, and the article usually ends with some such statement as " After considerable delay the water department shut off the water and the geyser subsided," or " The water department, after frantic efforts to locate the gates, finally shut off the flood."

When the broken pipe is examined, the iron is usually found in good condition, no thin places in the pipe, but something caused the break and the department is criticised.

Again, we find a thin place, a bubble covered by a thin layer of iron on the inside and the outside of the pipe, or a joint, like that in a roll where the iron never ran together and the water was held in the pipe by the tar filling the seam when the pipe was dipped, and it remained for a shock or a jar to start the water through and then the pipe let go and you had a flood.

I am not going to speak of blown joints, as they belong to another class.

In your fittings you will find these same faults and others. The knob on the side of a curve or over the place where the branch leaves the straight pipe leaks copiously. This is caused by a loose chaplet that was placed there to hold the core in place in the mold, and when the iron was poured it did not cement itself to the chaplet. You are laying some new lines and find your lead space a bit small, or have difficulty in entering a spigot into a bell, and perhaps have to chip off the bead. Then when the water is turned on and the pipe gets the pressure you see a large area that " sweats" showing porous or spongy iron in the walls of the pipe or fitting; all defects that may cause a bad leak some day.

You try to shut down a line, and after going through the motions of closing a gate, get a flood of water in the trench and have to go back and close other gates to stop it. Leaky gates may have the seat stripped off because something caught under the valve and the seat was not pinned

*Assistant Engineer, Public Works Dept., Boston, Mass.

in. A gate was operated by the crew and they could go on turning forever. The nut in the top of the valve was not pinned in when the gate was built and the stem has turned it out. You remove a gate box cover in the street and find the gate gland leaking badly. Either there was too little packing in the gate or it was not put in properly. I could go on indefinitely with these incidents, but they all go back to inspection.

In the course of my observations in the inspection of water-works equipment, I found the run of men making these things, that is, the owners, want to do a good job, sell their stock and make some money. It is usually some of the people in the lower list of employees who think it is smart to push along a piece that is not what it should be. This is where the inspection comes in. If your equipment is inspected (and by inspected I do not mean just looked over), many of these defects will be found; and if they can be corrected at the time and do no harm to the piece, the inspector will have it done, if not he will reject the piece and you do not get it in the system. I want to say right here that it is my belief that every inspector gets fooled or as the saying is "has it put over on him" sometime or other, whether he finds it out or not. The presence of an inspector where material is being fabricated will have a deterrent effect on any tendency to slight the work.

The inspection for the City of Boston is rigid, and I think all equipment should be rigidly inspected either at the place of manufacture or at the local yards or shops. In the inspection of main pipe the inspector finds a pipe with a scab on it and rejects it. Why? Well, the pipe was cast in a tight flask, and it is certain to begin with that nothing got out, therefore the piece of core or mold is in the walls of the pipe. Probably it has broken up into many small pieces and is scattered all through the pipe. Perhaps it will be found in a lump stuck in the narrow wall with only a thin layer of iron around it, a shell with a dirt core. At any rate the dirt is in the pipe and you do not want the pipe.

Some foundries now pour their pipe with a large riser or head the full diameter of the pipe. In fact it is really an extension of the pipe beyond the bead, this to catch all the dirt that may be floating on the iron when it comes up. Then they cut off this riser, leaving a good bead and clean spigot. But are you sure all the dirt got to the riser?

The writer knows of an instance where a piece of dirt broke off of the mold in a pipe 1.25 in. thick and caught in the narrow wall of the pipe and was imbedded in the iron. The pipe was passed to the hydraulic test and stood the required 300 lbs. without leaking; was subjected to the hammer test, and because the inspector's hammer happened to hit on that particular place and broke through, allowing the water to spurt out, exposing the weakness, the defect was found. Otherwise the dirt would not have been discovered, the pipe passed, and after being in the ground might have started a leak, the magnitude of which it is only possible to guess. There was only $\frac{1}{8}$-inch of iron in the wall on either side. Again,

inspection. Had this pipe been laid on poor soil where corrosion is rapid and pitting takes place, or been subject to water hammer, a leak would have developed, washing out the support, causing settlement, a broken line, a flood, damage and more criticism to the water department.

Roughness is another cause of rejection. I am inclined to think that the ordinary foundry roughness is smooth in comparison to the roughness that pipes acquire after a few years in the ground, due to tubercles forming on the inside of the pipe and retarding the flow of water many more times than the ordinary foundry roughness.

The inspection of main pipe has been so ably covered by other writers before this Association that I will not take your time to go into it more at length. However, I want to impress on you, in these days when it seems that every person not a producer is considered a load to the economic system, that an inspector, while not a producer, is a protector.

In the manufacture of gates or valves for the City of Boston Water Service we require the gates to be finished in a workman-like manner, to be inspected and tested. During the past fifteen years this service has had many hundred gates built outside of its own shop. The city furnishes everything necessary to assemble the gates, in the rough — iron castings, composition castings and flange bolts, gasket and packing. The contractor does all machine work, assembles the machined parts, tests and delivers the finished gates to our yard. The machine work is inspected before assembling and must conform to our standards both for finish and size and type of threads, and all similar parts must be interchangeable. The iron is tested through test bars 26 in. x 2 in. x 1 in., which are broken on supports 24 in. apart with a center load. They must show a deflection of at least $^{3}/_{10}$ in. under a load of 1 900 pounds before breaking. The castings are inspected at the foundry for size, thickness of walls, dirty or spongy iron, cold shuts or blow holes. The general character of the castings is noted, also their roughness. This latter does not affect the worthiness of the castings but it does affect the disposition of the machinists that work on them.

The composition is furnished in the rough as I have said before. This was made at a foundry having a contract to furnish our material, and test bars had been taken and pulled for tensile strength, after which the turnings were analyzed chemically. This has been done before the castings were accepted by the city.

Of course defects show up in the machining. If these unfit the piece for the purpose for which it was intended it is rejected. With iron parts, hard iron, blow holes and dirt show when the skin is turned off. Sometimes spongy and porous places are exposed, causing rejection. These defects are of such a nature that it is unreasonable to expect the foundry inspector to find them all. However, if there was no inspection some of them at least would find their way into the finished product and in a few years would give trouble. In testing the gates the City of Boston requires that

the gate be closed on one bell by a cap or head; the closed bell and gate is then filled with water, the valve is slightly raised, allowing the water to fill the bonnet, the air escaping through the gland which was loosened for that purpose. After the gate is full of water the valve is closed down tight and subjected to a pressure of 150 lb. per square inch, when any leakage through the valve either under the seats or between them is readily seen on the open side. The process is now reversed and the other side tested. This process duplicates the conditions in the line as near as may be and has been found very satisfactory. It shows up defects and exposes spongy places in the castings. It is preferred to the method of tapping in a piece of pipe in the bonnet and subjecting the bonnet and the parts surrounding the valve to the pressure but getting no pressure on the bells. This latter method is cheaper for the manufacturer and consequently is in almost universal use in commercial gates. It is my opinion that the commercial method is of advantage in the type of gate having loose discs because it tends to force both discs into seat at the same time at one operation. With the solid wedge type of gate which we use I do not advocate it; and as I said before, it gets no pressure on the bells. Our method will detect the slightest difference in taper between the seat in the body and the valve rings. As our gates are under pressure of from 25 to 100 lb. in the line and a very large percentage never get a pressure of over 50 lb., I believe 150 lb. test pressure is adequate. I do not believe in putting on an excessive test load and straining the castings uselessly, 50 per cent. overload being enough.

We also require the beaten in seats and valve rings to be pinned. This may seem a needless requirement as most commercial gate salesmen will tell you that their particular type of dovetail never pulls out. Certainly ours does not, and that is what we are after. The nut through which the stems in all gates over ten inches operate to lift the valve is also pinned in to prevent the stem from turning it out. This is also a matter of precaution and does not add but a trifle to the cost of the gate.

Sometimes we find gates, before acceptance, where the nut used to keep the stem from rising in the bonnet is omitted, depending on the gland to hold it down; others where the packing is poor; some leak between the flanges, showing defective gasket or loose flange bolts, leaks under the seats, between the seats, and it is not beyond reason to think that some of them would get into the line if it were not for inspection.

These instances are given to fix in your minds some of the defects that may be expected when materials *are* inspected and also you may infer what you get when they are *not* inspected.

In our hydrants, it is important in the compression type, of which the City of Boston has several sub-types, to see that the caps on the outlets are tight when the barrel is under pressure, that the gaskets between the stuffing box and the head of the barrel and between the bottom of the

barrel and the pot are good. In our newer type care must be exercised that the waste closes before the main valve has any more than just started.

Many of the water departments use iron or steel pipe. Do you get the material your order calls for? Do you inspect the lengths for splits and burrs before you line it with cement? Perhaps in a whole car load you would get not more than half a dozen defectives, but if these get into service and develop leaks it will cost you many times the cost of the tests to replace them, and the public is not inconvenienced by tests of this kind.

With brass fittings which are smaller, you are able to take them in your hand and naturally you or your foreman look them over and it is easy to see their general condition. But are the cocks tight, do they turn easily? What about the make up of the metal? This you would only know from inspection.

In this age of fierce competition, when each concern is striving for your orders, making hundreds, yes, thousands of the same kind of pieces, labor uncertain and overhead charges heavy, a fraction of a cent saved on each piece means profit. It is an easy matter to take a turning off of the inside of a pattern cutting down the weight while the outward appearance is not changed, put one less bolt in a flange or an ounce or two less metal in a stem, and the buyer does not notice it. I was told by the superintendent of the practice of one large concern in weighing ten of their pieces against ten similar pieces of their competitor and making theirs meet the competitor's. It means cutting down the factor of safety by which you guard the public. Some manufacturers resent the presence of an inspector in their works. They seem to think that their business honesty is being questioned. Well, to be frank with you, if the City of Boston, during the past few years, had not had some good inspectors in the Water Service to look out for its interests, the taxpayers would have received some pretty poor returns for their money.

I am of the opinion that a good article is worth a fair price, will last longer, will give the best service, and will cost less to maintain; that a cheap article is in every way temporary in its usefulness, will give poor service and cost more to maintain.

Why do we inspect our water works equipment? To see that we got what we contract for in number, weight, and quality.

Discussion.

Mr. Percy R. Sanders.* What is done in regard to testing the pipe fittings, 6 in. x 6 in., or 8 in. x 6 in.? I understand those are not tested under water pressure where they are made.

Mr. Lally. In the City of Boston we furnish our patterns and the contract is let to make the castings and the fittings from these patterns, and we have an inspector at the foundry where they are being made, and he inspects them with a hammer without any hydraulic test. He measures them, calipers the thickness of the walls, and does all the testing except hydraulic. They are not tested that way. The fittings for the high pressure fire system in the City of Boston were tested under 600 lb. hydraulic pressure in much the same manner that the main pipe were tested, and subjected to the hammer while under pressure. I will say that they got a lot of them that were porous. The pipes ran very thick, and it is hard to get thick pipe without getting porous iron.

Mr. David A. Heffernan.† What is the percentage of copper in the alloys of the brass fittings?

Mr. Lally. We have three grades. The No. 1 is used for stems and bolts, and calls for 88 parts of copper, 10 of tin and 2 of zinc.

Our No. 2 metal is used for everything else except stems and seats that have to be beaten in. It is composed of 84.2 copper, 7.4 tin, 6.3 zinc, 2.1 lead. It is a soft metal and makes a good valve for the inside of the gate, but where it ever came from I do not know. It has been in the water specifications for twenty years to my knowledge.

The No. 3 metal that we use is nothing but ordinary brass, — 3 of copper and 1 of zinc. That is only used for valve seats that are beaten in.

Mr. Heffernan. I think the City of Boston uses plug curb cocks — as high as $1\frac{1}{2}$ in. If that is true, is there any difficulty in regard to operating those plug cocks?

Mr. Lally. Inch and a half, I think, is the largest size that we use, but we formerly used a 2-inch. We put in an inch and a half cock, with increasers, usually, where a 2 in. pipe is used immediately behind the cock. I will say that they do open very hard after awhile. Operators drop heavy wrenches down, which has a tendency to drive the plug in, and sometimes they have to be dug out.

Mr. Heffernan. Some communities are using plug cocks, as high as 2 in. I can't see how they can get service for any length of time from a large cock installed under ground, or how they can depend upon its working.

Mr. Lally. I will say now that they are using a 2-in. valve with an extension on it on 2-in. cast-iron pipe for services instead of lead. It is the regular standard commercial valve with an extension stem coming up

* Superintendent Water Works Concord, N. H.
† Superintendent Water Works, Milton, Mass.

to the street, and a small nut put on that would not be operated by a regular gate wrench. Our regular gate wrenches take in everything from 4 in. up to 12. The 16-in. has a different size nut on the top of it. Formerly they used some of these 2-in. gate valves, and there was nothing to operate after the wrench was dropped down into the hole. So that they have brought these up in an extension to a 1-in. square nut just under the cover.

Mr. E. M. Nichols.* How long have these specifications been in use?

Mr. Lally. I think since '98. But for the benefit of the gentleman, who evidently takes a wrong impression from the date, the metal can't be beat to-day.

Mr. Nichols. I am inclined to disagree decidedly with the gentleman that the the metal can't be beat. It can be decidedly improved upon.

Mr. Richard J. Flinn.† What is considered the best packing for the stuffing-box?

Mr. Lally. I won't say that we consider it the best, I do not — but what we use is ordinary wicking that has been boiled in edible tallow.

Mr. Flinn. We use granulated cork for packing, and have for ten years.

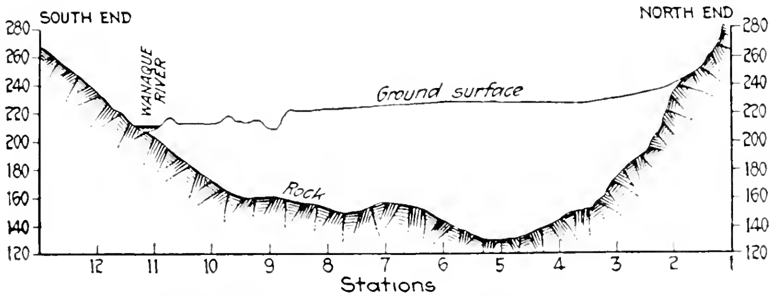
* Civil Engineer, Philadelphia, Pa.
† Mechanical Engineer, Boston, Mass.

THE DEEP CORE-WALL OF THE WANAQUE DAM.

BY MAJOR ARTHUR H. PRATT.*

[*Read September 13, 1922.*]

The Wanaque Dam, under construction by the North Jersey District Water Supply Commission, will impound the waters of the Wanaque River, one of the tributaries of the Passaic River, at a point about 25 mi. north of the city of Newark. The Wanaque Reservoir, which will supplement the present Pequannock River supply for Newark and will also serve other neighboring municipalities, will impound between 11 000 and 27 000 million gal., giving a safe yield of 50 to 100 m.g.d., depending upon the needs of the municipalities which decide to enter the project. The reservoir will be about 6 mi. long and 1 mi. wide.



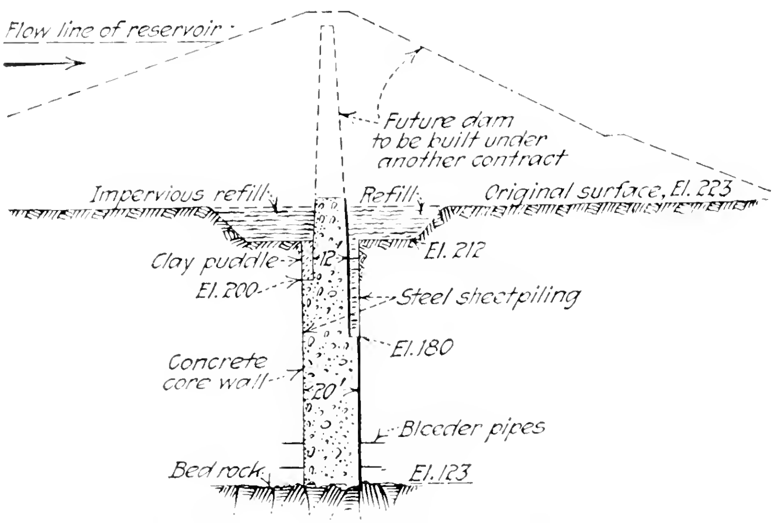
LONGITUDINAL PROFILE OF WANAQUE DAM SITE.

The site of the dam is across a valley about 1 500 ft. wide which is to be closed by means of an earth dam having a concrete core-wall extending to bedrock which outcrops on both hillsides but at the bottom of the valley dips to about 100 ft. below the surface. The rock is gneiss and the overburden is water-bearing sand and gravel. The present channel of the river crosses the site of the dam near the south end and the river bed is partly on the ledge rock which gradually dips away from the river to the deepest place near the middle of the valley. The method adopted for constructing the core-wall was to drive two walls of steel sheet piling across the valley, excavate between them, meanwhile bracing the steel sheeting with timber, and then fill the trench with concrete. The type of sheeting used was the Lackawanna, arch-web, 35 lb. section. Previous to putting down the sheeted trench, a stretch of open cut, with sloped sides, was taken out with a steam shovel, giving a level path upon which to erect

*Chief Engineer North Jersey District Water Supply Commission, Newark, N. J.

the frame for guiding the piling and for working the two pile-driving rigs, one on each side of the trench. These rigs had an A-frame 75 ft. high, with an extension to a total height of 92 ft., giving a clearance sufficient to handle and mesh one 50-ft. pile into another when the latter has been driven about 10 ft. Rigs were equipped with Warrington No. 1 steam hammers and mounted on skids sliding on sills laid normal to the trench.

Pile-Driving Methods. In driving the piling the method used was to put the sheeting down as a wall and not as a series of individual piles. First a portable guide frame 48 ft. long made of 12 x 12-in. timbers was set up over the deepest part of the trench. This frame was constructed so that it could be adjusted to various widths. The aim being to obtain

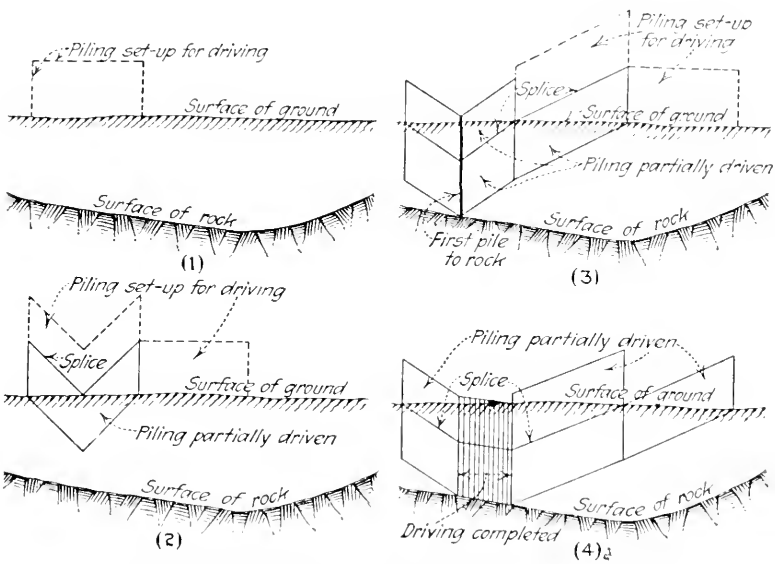


SECTION OF DAM AT MAXIMUM CORE-WALL DEPTH.

a trench 20 ft. wide at the bottom, and there being no experience upon which to determine the probable deviation of sheeting for such deep driving, the guide frame was first set to a width of 22 ft. After the piling was driven, the average top width was found to be actually 21.5 ft. The deviation from the vertical at the rock was found to be about 6 in. for each wall of piling, sometimes wider and sometimes narrower than the width at the top. On top of the rock the slope of the ledge surface forced the piling out of line so that the narrowest trench was 18.6 ft. and the widest was 24.4 ft. Later on with this experience to govern and for the shallower trench the width was reduced to 14 ft.

A wall of 50 ft. steel piling was set up on each side of the guide-frame and driven into the ground a few feet so as to hold the toe in place. Extreme care was exercised for the first set to have the piling true and plumb. This precaution was found to be very important as the first piles driven serve as pilots for all succeeding piles. Succeeding frames were also set

up very carefully. After the first stretch of piling was erected, driving was begun on a set of three piles at the middle of the frame. When the first three piles were driven a few feet the adjacent three on each side were driven, and so on, the rule being, in general, to drive no pile more than 4 ft. in advance of its neighbor. This method was continued until the top of the middle pile of the set was down to the surface of the ground, the bottoms of the adjoining piles then being in staggered diagonal lines to the surface of the ground. The frame was then moved ahead, another frame-full of piling set up adjoining the first, and driving resumed until the new set



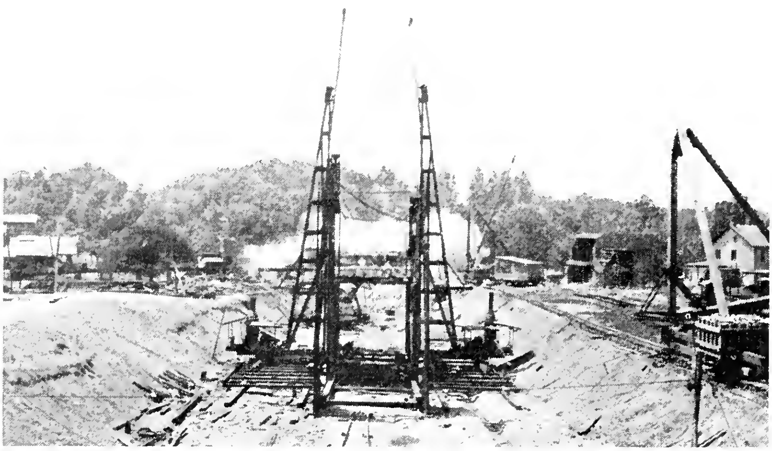
SEQUENCE OF OPERATION DRIVING SHEET PILING.

and adjoining members of the first set were down to the surface of the ground, the end piles being always left stepped-up in approximately 4 ft. steps.

As required, additional lengths of piling were spliced on top of the lower set by means of a 7-in. channel and a $\frac{3}{8}$-in. x $6\frac{1}{2}$-in. plate, bolt-holes to fit being previously punched in the ends of the piles. In this manner, by gradually working the wall down with its bottom to a slanting line, one of the steel members finally intersected the line of rising rock as shown more clearly on the diagram. While the first frame was set up over the deepest point, the first pile to strike rock was some 50 ft. to the south. Driving to rock continued then until the rock outcrop at the north end of the dam was reached.

The lengths of piles to be driven were at first determined by scale from the rock profile developed by the original borings, but on account of the great unevenness of the rock it was later found to be better to make

careful soundings, with the pile-driving rig and a steel rail, on the line of piling to determine the appropriate lengths of piles more accurately in advance. After the sheeting had been extended to the north end, the pile-driving rigs were moved to the other end of the walls of piling, the frame was set up and the same methods used to extend the sheeting to the south end of the dam. When possible, sets of three piles were driven at one time but when the penetration became difficult two piles were driven and finally for the deepest part only one pile was driven at a time. The maximum length of penetration was 84 ft. and the slowest driving in that vicinity



Sheet Piling Rig, Guide Frame and Derrick.

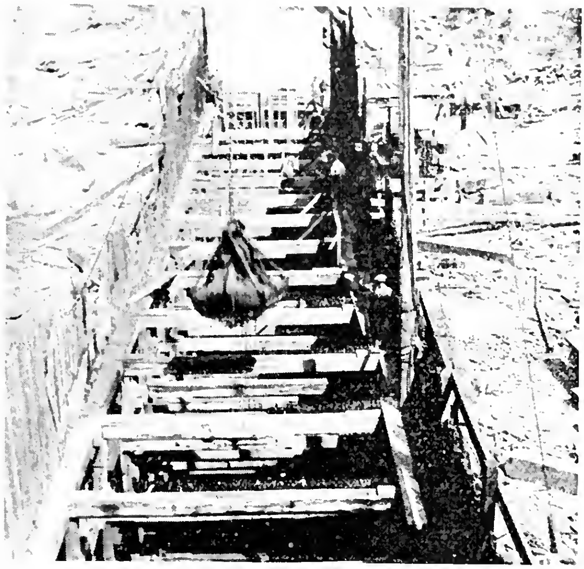
was some 90 blows to the inch. The vertical position of the piling as established by the first set driven was maintained throughout the job so that no special wedge shaped pieces were required.

A typical gang consisted of 1 foreman, 1 pile-driver operator and 6 pile-driver men for each rig. Two rigs were run under one general foreman and high pressure steam was supplied from a central plant so that a fireman was not usually employed with the driving rig. Pile-driving progress for two rigs is shown in Table 1.

TABLE 1. — Progress of Driving of Steel Sheet-Piling.

Month.	Sq. Ft.	Month.	Sq. Ft.
April, 1921	5 600	November	900
May	6 500	December	200
June	9 200	January, 1922	100
July	14,700	February	15 800
August	5 200	March	6 000
September	6 600	April	9 900
October	12 800	May	6 400
		Total	99 900

Excavation. As soon as the driving was completed at the north end excavation was begun with clamshell buckets operated from stiff-leg derricks running on a track on top of the west bank. As fast as the trench was excavated the sheeting was supported with 12-in. x 12-in. braces in bays 10 ft. on centers with the wales and braces spaced 6 ft. apart vertically for the upper 32 ft. of the trench. Below this the spacing was reduced



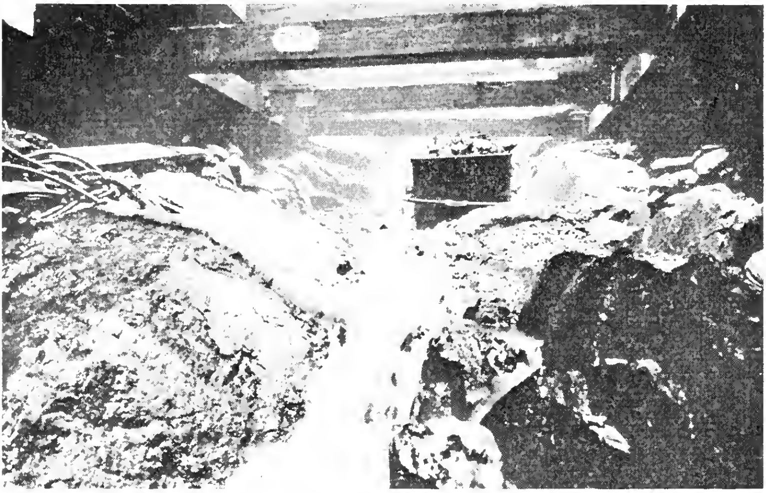
TIMBERING OF DEEP-CORE WALL TRENCH.

to 3 ft. vertically and subsequently altered to double sets 6 ft. apart. Rangers 14 in. x 14 in. and 12 in. x 14 in. braces were used for the lower portion of the trench. Pumping was required immediately after the installation of the top set of bracing. Two 8 in. discharge, Morris Machine Co., 60 in. diameter, centrifugal dredge pumps were installed and dredged a considerable yardage of sand and gravel out of the trench, depositing it on the downstream dam embankment, besides pumping water. In addition the following pumping equipment was used: Four No. 9 Pulsometers; two 5 in. Emersons; Two Lawrence 5 in. electric centrifugals and one Worthington electric 100 h.p. 6 in. discharge, centrifugal. The quantities of water pumped are given in Table 2.

TABLE 2.—MONTHLY OUTPUT OF TRENCH PUMPS IN MILLIONS OF GALLONS.

March, 1921	.6	December	90.5
April	1.9	January, 1922	81.0
May	.2	February	70.5
June	3.2	March	120.3
July	41.5	April	115.8
August	138.9	May	116.6
September	102.4	June	111.4
October	101.2	July	94.2
November	85.8	August	19.2

Rates of 5 000 and 6 000 g.p.m. were pumped in February, 1922, when the longest stretch of deep trench was open. The total pumpage was about 93 000 million foot-gallons.



BOTTOM OF DEEP CORE-WALL TRENCH.

BOTTOM OF DEEP CORE-WALL TRENCH.
Good Contact between Steel Piling and Rock.

Due to the porosity of the material and the low rainfall, the ground water level was very considerably lowered during the fall and winter of 1921-22. In general it remained about 20 ft. above water level in the trench. The result of this was to appreciably reduce the pressure on the timber tracing. After a few timber sets had been put in and the trench excavated about 40 ft. deep the bracing began to show strain; one wale

cracked longitudinally in about the middle, some of the bracing cut into the wales as much as $\frac{1}{2}$ in. and some of the braces split at the ends. A closer vertical spacing was considered, but the only change actually made was to substitute oak for pine bearing plates at the ends of the braces and to frame the timber with even greater care than before so as to be sure of a bearing over the entire 144 sq. in. section.

As the trench was deepened the ground water dropped and the pressures apparently never again reached those which obtained in the more

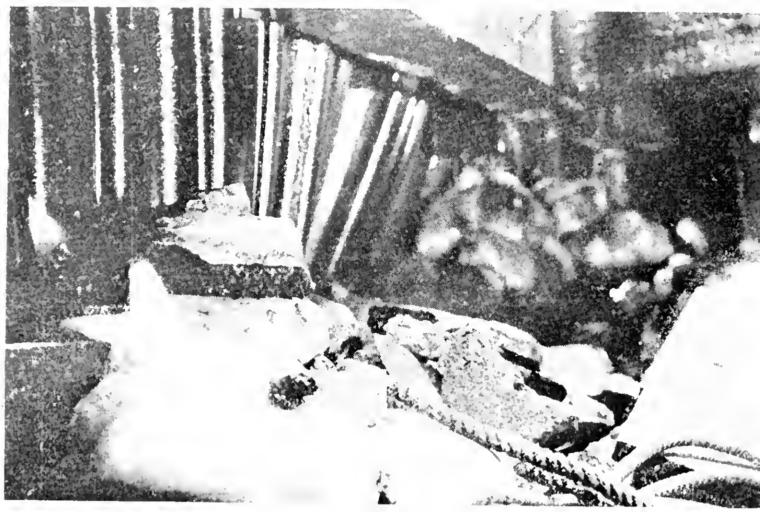
Bottom of Deep Core-Wall Trench.
Good Contact Between Steel Sheet Piling and Rock.

shallow trench. Most of the braces when removed were sawed and cut out with no great difficulty and some were pulled out with a cable from a derrick hoisting engine without any cutting. In general, the contact of the steel piling with the rock surface was found to be most satisfactory but in a very few places the piling had encountered rock fragments near the bottom and had been twisted out of its interlock. There were a few piles that had been overdriven and "fishhooked." A small pile hammer was rigged on a derrick set upon the berm of the sloped excavation and any piles not showing a tight contact were redriven as was found necessary.

Turned up piles were burned off. For a stretch of about 20 ft. on one side in the bottom of the deepest section of the trench an additional set of short piling was driven inside of the original set. This was the only place where a double set was required.

Method of Concreting Core-Wall. As soon as the earth was excavated from the northerly end of the trench, the concreting of the core-wall was begun. Aggregate was obtained from a gravel bank on the opposite side of the river located on a terrace about 35 ft. above river level about one-

half mile away from the core-wall. The material was excavated by means of a steam shovel, hauled to and run through a crusher and a revolving screen. The portion of the output of the screening plant which could be used at once was hauled directly to the concrete mixer and the remainder stored in the excavated part of the pit for future use. There was about 50 per cent. of excess sand in the pit which had to be wasted. The concrete mixing plant located 300 ft. from the core-wall trench consisted of aggregate storage piles feeding into bins by a derrick and two Ransome,



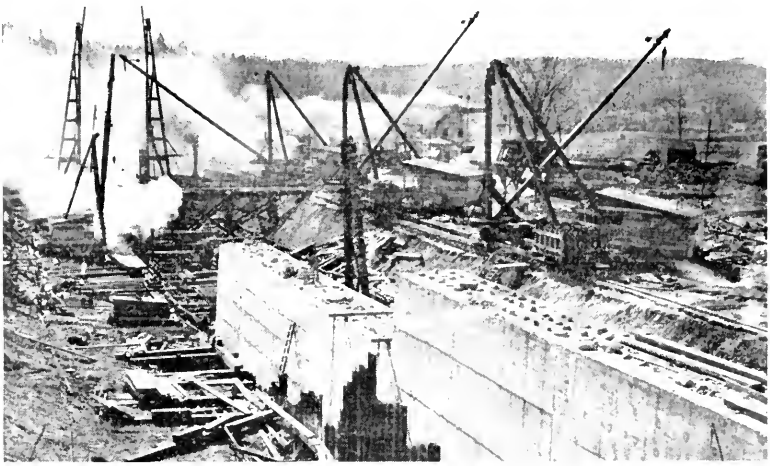
Bottom of Deep Core-Wall Trench.
Bad Contact Between Steel Sheet Piling and Rock.

size 53, mixers. Mixed concrete mostly proportioned 1:2½:5 was deposited in bottom-dump buckets hauled to the core-wall trench on narrow-gage flat cars and transferred by stiff-leg derricks to the concrete forms. In the bottom of the trench, on account of the interference of timbering, concrete was placed through hoppers feeding into a vertical 10-in. steel pipe.

In the first part of the work the water in the bottom was handled with no difficulty by means of blind drains or pipes on the sides of the trench next to the sheeting, but as the deeper portion of the trench was reached the quantity of water increased and begun to interfere with placing the concrete. The ground water back of the sheeting began to leak through and flow onto the concrete up to a level some 20 ft. above the bottom of the trench.

To obviate this trouble holes were burned in the sheeting near the bottom and 2 in. pointed and perforated pipes, 3 or 4 ft. long, were driven into the earth back of the sheeting. These drained the water away from the back of the piling so that the flow into the trench was largely confined

to these bleeder pipes and was easily controlled. The bleeders were also useful in holding the ground water level down so that there was no difficulty in placing the subsequent layers of concrete. For the concrete in the deepest section additional precautions were used. The concrete was placed in short stretches, 10 or 20 ft. long, and first a concrete bulkhead about 6 in. wide and 2 ft. high was built on either side about 2 ft. from the sheeting. Back of this wall a blind drain or pipe, sometimes connected with the bleeder pipes, carried the water ahead. Between these bulkheads



UPPER PART OF CORE-WALL UNDER CONSTRUCTION.

concrete could be placed in the dry and afterwards the space back of the bulkheads was concreted, blind drains and drain pipes being cut off periodically.

Concreting was carried on from the north end of the trench towards the middle until the deepest point in the excavation was reached, Sta. 5+00, where the principal pumping plant was located. Operations were then undertaken part way across the valley near Sta. 7+50, at a point where there was a natural sump in the rock. Here another pump was installed and operations by the same methods as used before continued in the opposite direction until the gap between the new pump and the main pumping plant was filled. Then the closure at the deep place was undertaken, the space between the finished sections of core-wall being about 40 ft. Parapet walls 6-in. wide were built longitudinally across this stretch about 2 ft. inside of the sheeting; and the water which came underneath the piling or through bleeder pipes was concentrated on either side between the parapet and the steel piling, leaving the center clear and dry to be filled with concrete. When the center wall had been carried up about 6 ft., the spaces between the parapets and the steel piling were filled with rock fragments and the top was sealed over with concrete from one wall of steel piling to

the other, leaving vertical steel pipes built into the concrete for pump suctions and float wells. The pumps were then arranged in three sets, one having its suction on the upstream side, the second on the downstream side and the third was arranged so that it could be switched to either side when one set of pumps of the three was being raised. By this means, alternately raising one pump at a time and concreting under it and building the suction pipes up, the closure in the deep section was accomplished. Meanwhile concreting proceeded at the river end of the trench where the rock is not so deep and was completed in that stretch before the final closure was made.

To insure that the concrete in the closure section might never be flooded the pump sections were built up clear to the top of the sheeted trench and pumping continued until the last batch of concrete below ground water level was placed.

TABLE 3.— Monthly Progress of Concrete in Core-Wall.

	Cu. Yds.		Cu. Yds.
September, 1921	94	March	1 484
October	932	April	1 750
November	1 307	May	6 095
December	315	June	5 377
January	1 621	July	5 862
February	2 061	August	8 502
		Total	35 400

The refill of the sloped excavation on the upstream side with rolled impervious material and on the downstream side with sand and gravel placed by the hydraulic method — both direct pumping and slushing from a dry fill — is in progress.

The construction of the core-wall was under the direct supervision of N. C. Holdredge, Assistant Chief Engineer, the contractor was W. H. Gahagan, Inc. and subcontractor for driving the piling was J. Roy Horton.

Discussion.

Mr. Robert Spurr Weston.* What was done with the piling after the core-wall was put in?

Mr. Pratt. We pulled some of the piling in the north end to use a second time to close up the end in the river. I did not go into the detail of saying that in building this wall to the river there was a short stretch which was left to be finally closed after the deep trench was filled. The rest of the piling was cut off at the surface of the ground and left in place.

* Consulting Engineer, Boston, Mass.

TOPICAL DISCUSSIONS.

THE FLUSHOMETER.

[*September 15, 1922*]

MR. FRANK. A. MCINNES.* I should like to ask our members what experience they have had, if any, with flushometer closets. With the advent of modern plumbing requests are coming along for 4 in. pipes where we have been granting 3 in.; for 3-in. pipes where we have been granting 2 in.; and for 2 in. where we have been granting 1 in., and I now have one case in the new Chamber of Commerce Building where a modest request is made for a 6 in. This is all caused by the demands of the flushometers.

We have not had sufficient experience to know what the flushometer requires for proper service, nor can any of the plumbers I have talked with give the information. They simply claim they must have the water.

From the present outlook, the flushometer, operated without a tank directly from the pressure, may easily become a serious matter, perhaps in time rivalling our friend the fire pipe.

MR. CARLETON E. DAVIS.† What pressure do you have to have for the flushometer?

MR. MCINNES. I can only answer by saying that all of our pressures appear to be satisfactory; from 45 to 90 lb.

MR. DAVIS. Is there a limited pressure?

MR. MCINNES. I do not know.

MR. DAVID A. HEFFERNAN.‡ Mr. Gordon M. Fair, Instructor in Sanitary Engineering, Harvard Engineering School, read a paper before this Association on February 9, 1921 on the Flush Valve. This paper was published in the JOURNAL, June, 1921, and contains much valuable data.

In large cities where flushing valves are used in modern buildings, facilities must be adopted by the storage of water in tanks, or to make independent corrections by direct pressure to the valves. This latter method requires larger services and is objectionable to the water departments.

In my opinion the use of these valves by direct pressure should be discouraged as much as possible by water-works officials.

PROF. GEORGE C. WHIPPLE.§ The Plumbing Committee of the department of Commerce working in Washington the last year studied

*Division Engineer Public Works Dept., Division of Water, Boston, Mass.
† Chief Bureau of Water, Philadelphia, Pa.
‡ Superintendent Water Works, Milton, Mass.
§ Professor of Sanitary Engineering, Harvard Engineering School.

that very carefully at the Bureau of Standards. We have not as yet tested the flushometer, but have tested the ordinary closets. Experiments have given us the rate of flow each second the time the chain is pulled until the flush goes out. I think when we get through with our work we will know just what is needed for rate of flow, both for the flushometer and the other kinds. At the present time, with the ordinary closet, you will find the maximum rate of discharge is about a gallon a second. It runs up to that and then drops off.

Mr. McInnes. There is the whole point. It is the maximum demand for the flush closet that we are looking for.

Prof. Whipple. We will probably have that part of the work done within three or four months.

Mr. McInnes. You are probably aware of the great demand for flushometer closets. It is coming up in every new building.

Prof. Whipple. People are asking for it for small houses, too, which is the worst feature of it all. I do not think the plumbers really like the flushometer, it is the architects, rather than the plumbers themselves.

Mr. McInnes. It is something we have got to meet.

Mr. W. C. Hawley.* I have had some experience with the flushometer proposition. Occasionally, in the case of a private house, the demand is made for a service line from twice to five times the size which would be necessary for an adequate supply for the house if it were not for the flushometer. There is not only the question of the increased investment in service line and meter, without any corresponding increase in the amount of water sold, but in the case of a water works carrying a high pressure on its mains, there is the added danger of "water hammer." I have taken the position that while we were willing to furnish all the water that was wanted, we would not undertake to furnish ninety-nine per cent. of the water in one per cent. of the time, and that if they wanted service of that kind, some arrangement for storage should be provided. We had one case where there were 20 flushometers installed in a school house, with a demand for a 4 in. service line, or at the very least a 2 in. service line. At our suggestion, however, they installed a surge tank in which water is stored with air under pressure, and a 1 in. service line has given satisfactory service for several years past.

Prof. Whipple. There is one other phase of that problem. We find that a very large part of the difficulty of designing plumbing systems has to do with the coincident discharge of the fixtures. That is a thing about which we are absolutely ignorant. If a half dozen flushometers are going off at absolutely the same instant, then there must be a big supply, but if one discharges after another, if they take turns, then it is not necessary to provide for as large a supply. The thing we need to look into is the question of coincident discharge. How much of a factor of safety must

* Chief Engineer Pennsylvania Water Co.

be provided on account of the different fixtures going off at once? There is where the crux of the problem lies.

Mr. McInnes. Absolutely.

Mr. F. N. Connet.* Some years ago I saw a water closet in which a large air chamber was used in connection with the flushometer, and that made a storage of about a cubic foot of water at the point where it was needed, so that the compressed air aided in flushing the closet without a very large, sudden draft on the main pipe. I thought the idea was good, but it does not seem to have been followed out.

Mr. M. N. Baker.† It is interesting to hear that at this seemingly late day the flushometer is coming rapidly into use. I well remember writing an illustrated description of the device when it was brought out twenty-five years ago (*Engineering News*, 1897-II, P. 260). Quite recently I was wondering why I did not see or hear of the flushometer more frequently. It is interesting to know that all of a sudden something seems to have happened. Somebody must be getting behind the device, pushing it hard, either the manufacturers, or else the architects have become suddenly convinced. It would be interesting to have some light thrown on the recent movement to indicate whether it is likely to die down or go on and become a big problem for water-works men.

Mr. Davis. Does it really flush any better than the old time tank? Is it any more sanitary? Isn't it merely an indication of the tendency of modern extravagance?

Prof. Whipple. It looks neater and avoids the unsightly tank. It is a matter of luxury.

Mr. Frank A. Marston.‡ I would like to suggest that if this matter is going to be studied it would be worth while to measure the rate of discharge from mills such as are in New Bedford, and big schoolhouses, where many flushes are to be expected almost simultaneously, as for instance, during the first few minutes after closing time in a large mill, or at recess time in a school. In an office building, the conditions are entirely different. But little information is available on this subject, and it would be helpful if something could be done to accumulate such data.

Prof. Whipple. We have not taken any steps to find that rate. It would be necessary to use meter records.

President Barbour. If you had some kind of record of discharge in large buildings from minute to minute right through the day you would get some information.

Prof. Whipple. It would be a simple matter to keep a stop watch and find out how frequently the discharge came. That has been done in the Grand Central Station in New York for a half hour and record kept of the number of times they heard the discharge go out, and it is surprising

* Builders Iron Foundry.

† Associate Editor *Engineering News Record*.

‡ Of Metcalf & Eddy, Boston, Mass.

how infrequently there are simultaneous discharges. I think we have been allowing for too big a factor of safety.

Mr. William W. Brush.* I have not had any personal experience with this, Mr. President. So far they have not affected materially the supply, except the question of the size of connections. We have two pressures in the upper part of Manhattan on account of flushometers. When the Catskill system came into it, it was planned to place the greater part of northern Manhattan, which has previously been tower service, on the Catskill service, with a gradient at that point of around 285. That gave a pressure of between 40 lb. and 50 lb. in that section which was previously 60 lb. or more. Complaints came in from the large new apartment houses in that section, because they were using flushometers, and with the 40 lb. pressure at street level — they were about six story apartments — they did not get satisfactory flowage for the flushometers, so that we changed over quite a large area and put it back on the tower so as to get satisfactory service.

Painting Fire Hydrants

[*September 15, 1922.*]

Mr. Carleton E. Davis.* In Philadelphia we paint our fire hydrants yellow. Red paint on fire hydrants is seen all right in the daytime, but you can't see them at night. The same thing holds true with green. The aluminum tops are too expensive; it takes too long to put them on. Finally we tried yellow paint, and it appears to be a very satisfactory color. The firemen like it, and it stands out conspicuously. You can see yellow in the night time under light, you can see it in the day time, and on a foggy or misty day. Furthermore, yellow is a bright contrast in the streets. The electric light and telephone pole is generally a dark color, and with the fire hydrants painted yellow they stand out conspicuously. The traffic policemen tell me they like the yellow hydrants because there is no excuse for people parking their cars in front of the hydrant. Ordinarily with the fire hydrant a dark color they will pay no attention to it; but when you paint it yellow the traffic officers will say, "Can't you see this yellow fire hydrant?" We do not pick the very bright color, but take a shade called "4", which is something like an old fashioned New England pumpkin in its luscious and ripe state.

Incidentally, we are painting our pumps the same color in place of green, formerly used. Our largest pumps, which are 12 twenty million gal. pumps, are painted yellow with black trimmings, with the steam pipes painted yellow. It has a wonderful effect on the men and tends to keep them awake at night. It affects the eye, and has a good psychological

* Deputy Chief Engineer, Bureau of Water, New York.

† Chief of Bureau of Water, Philadelphia, Pa.

effect. Yellow reflects the light on the moving parts, so that they are more easily seen. It is rather a shock when you think of painting pumps yellow, but you will remember that in the old times yellow was the standard color for marine engines, and it was for a purpose, because it lightened up the dark parts of the engine. We have come back to yellow, and shall keep on with it. It is a first class hydrant color. The base of the hydrant we paint black, about 6 to 8 in. up from the ground.

Mr. David A. Heffernan.* The only trouble with that color would be that you would have to go over your hydrant more often; it would be apt to get dirtier.

Mr. Davis. Even if they do get dirtier, the yellow shows through the dirt. If you paint green or red or black, the dirt seems to obscure them even more than with yellow. The yellow is a penetrating color and it seems to come through the dirt.

Mr. Heffernan. We paint ours black, and just use a bronze paint.

Secretary Frank A. Gifford. How often do you paint them?

Mr. Heffernan. Every two years.

Mr. Davis. We have not had as many collisions with the yellow hydrants as we had with the other colors. They are conspicuous to the automobilists.

*Superintendent of Water Works, Milton, Mass.

FLORENCE M. GRISWOLD.

Florence M. Griswold was born in Hoboken, New Jersey in November, 1834. He received his education in the public schools and at Wittenburg College, Springfield, Ohio. During the Civil War he served with the Union forces, enlisting from Mainville, Ohio near Cincinnati. At the close of the Civil War he returned to Cincinnati and became Special Agent of the old North American Fire Insurance Company of New York, and under the supervision of his father, Jeremiah Griswold, General Agent of the Company spent several months in general field work in that territory. In 1866 he was appointed Assistant General Agent of the Company and served in that capacity until 1870. In the succeeding five years he was connected in various responsible capacities with several of the principal fire insurance companies, becoming in 1875 the General Inspector of The Home Insurance Company of New York with headquarters in New York City. Since that time he has had particular charge of the special hazards and technical work conducted by The Home Insurance Company throughout the whole field of its operations.

Mr. Griswold's father, Jeremiah Griswold, was himself a well known insurance man, having been associated with the Aetna. Jeremiah was the author of "Griswold's Handbook on Adjustments," "Griswold on Insurance," "Underwriters' Text-Book" and other authoritative publications on various phases of the insurance business.

At the time of his entry into fire insurance, the business was admitted to be a "System of magnificent guessing" as to hazards and rates, wherein a risk was assumed almost without regard to physical or other hazards. A short experience convinced Mr. Griswold that such method was entirely empirical and he began to study the needs of the situation in order to reach a basis having some evidence of scientific principles underlying it, and to put into operation the conclusions arrived at. Among the most important of these was the realization that the obligations existing between the insurer and the insured are properly mutual, and that anything which tends to the profit or safety of one is of like value to the other.

Building upon this foundation, he undertook to make himself familiar with the processes and methods of all classes of manufacturing industries and the fire hazards incident to each, and then began the work of making better that which came under his supervision. He assisted in the organization of many of the inspection bureaus, and had an active hand in the formulation of a number of schedules for rating industrial plants. From the length of his service and the knowledge gained by his unceasing study and investigation of fire hazards, he perhaps became one of the best versed men in his profession and was frequently referred to as "The Dean of Fire Insurance Engineers."

Following, naturally, in the line of preventing the occurrence of fires, arose the necessity for their extinguishment. In this line of investigation he devoted much attention to the betterment of public and private fire protection, and in pursuit of this particular line of knowledge and information, Mr. Griswold was brought into intimate contact with the fire and water departments of many of the principal cities of this country, and was known by them as an authority in this line. For many years he was an ardent advocate and a strenuous worker in an attempt to secure universal standards for all classes of fire-fighting facilities and utilities, especially for public fire hose connections. The need for standard hose and hydrant threads was apparent, and in view of the broad experience and wide acquaintance he had throughout the country, the National Fire Protection Association selected him to head a special committee to secure the adoption of a universal standard. Mr. Griswold accepted the task with full knowledge of the many attempts and failures of past efforts for its accomplishment. As the result of his persistent effort he secured the official endorsement of his coupling by all of the leading and most influential organizations of this country, thus establishing a standard coupling, the adoption of which has become general in all parts of the country, and in 1917 was approved and adopted by the United States Bureau of Standards as the "National Standard Hose Coupling and Hydrant Fitting" for public fire service.

Mr. Griswold was a member of the Grand Army of the Republic, the American and the New England Water Works Associations, The American Society of Mechanical Engineers, and associate member of the International Association of Fire Engineers, to which organization he has for many years been the accredited delegate from the National Fire Protection Association; and Honorary Foreign Correspondent of the British Fire Prevention Committee, and an Honorary Life Member of the National Fire Protection Association.

He was active in his line of work, kept in close touch with all technical matters affecting fire prevention work, and few men have had so important a part in bringing fire underwriting to a point where it can in some truth be called an applied science.

During his business connection, embracing forty-seven years in the study of the technical principles of fire underwriting, many authoritative publications on fire prevention were prepared for The Home Insurance Company, whose interests he held paramount to all others.

We can testify to his strict integrity and loyalty, and regret with all others who had the pleasure of his acquaintance, that so much has been lost to the fire insurance business. Morally, mentally and physically he was a high type of man, and he will be sorely missed by all.

PROCEEDINGS.

The following is a synopsis of such parts of the proceedings at the New Bedford convention as appears to be of value for the record.

Forty-First Annual Convention.

New Bedford, Mass.
September 12, 13, 14, 15, 1922.

The Forty-First Annual Convention of the New England Water Work Association was held at New Bedford, Mass., September 12, 13, 14 and 15, 1922.

The sessions of the convention were held on the top floor of the New Bedford Hotel, where also were provided accommodations for the exhibits of the Manufacturers.

The Convention was called to order at 10.30 a. m., September 12, by Stephen H. Taylor, Superintendent of the New Bedford Water Works.

Mr. Taylor. Mr. President, ladies and members of the Association: It gives me great pleasure to introduce to you Hon. Walter H. B. Remington, Mayor of the City of New Bedford. (Applause.)

Address of Welcome by Hon. W. H. B. Remington, Mayor of New Bedford.

Mr. Remington. Mr. President, ladies and gentlemen of the Convention: During the past summer it has been my privilege to extend a word of welcome in behalf of the City to several Conventions, and it has been a pleasure to do so in each instance. It is no less a pleasure to extend New Bedford's hearty welcome to the representatives of the New England Water Works Association, and I do so with the best wish that your stay with us may be enjoyed. New Bedford has a particularly warm spot in its heart for the New England Water Works Association. For many years our Superintendent of Water Works, Robert C. P. Coggeshall, was prominently indentified with your Association in an official capacity, and by reason of his enthusiastic appreciation of the work which the organization was doing for the procuring of pure water we have come to know you well. Our system, which you will inspect before you return to your homes, is a monument, in a way, to Mr. Coggeshall's fealty to the ideals of the New England Water Works Association. We are proud of it, and we are proud of him and of the members of the Water Boards who have worked with him to achieve the results which we are able to show you.

You will learn, if you do not already know about it, that others appreciate our system as much as we do ourselves, and are anxious to share in what we have. We are not unwilling to share but we do have the same feeling that induced the ox in the fable to kick when somebody farther up the stream polluted his drinking place. We are satisfied to be let alone, and we cannot see any good reason why we should be disturbed in the possessive use of a water system which we have developed and protected at considerable expense.

But we cannot expect you to be interested in our affairs during your visit to New Bedford. Your Convention has affairs of its own, which will doubtless claim your attention. But we do expect you will have a good time while you are in New Bedford, and if there is anything lacking to that end just mention it to Steve Taylor — he will do the rest. (Applause.)

Mr. Taylor. Mr. President, it is a pleasant priviledge to introduce Mr. William Ritchie, President of the Board of Commerce of New Bedford. (Applause.)

Address of Welcome by William Ritchie, President Board of Commerce.

Mr. Ritchie. Mr. President, ladies and members of the New England Water Works Association: The Board of Commerce represents the industrial, mercantile and civic activities of the City, and they welcome you for two reasons: First, we are always glad to see visitors; second, we are proud of New Bedford's achievement in the development of its water works, due to the foresight and sagacity of some of our citizens.

My predecessor as President of the Board of Commerce, Mr. Edmund Wood, was a member of the original commission which started this development. When those far-seeing business men started their work they were criticised by officials of other cities, and it was with a great deal of effort that they prevailed upon our wise legislators to permit New Bedford to finance the matter from time to time. The judgment and vision of those men have been demonstrated by our water system as developed to-day, as I think that you will agree with me after a visit to the works.

We are indeed glad to have this convention of experts meet in New Bedford and observe our system, and we hope they will endorse our opinion of the system. We hope also that they will observe at the same time the great industrial and civic growth of our city, which is also due to the type of men who were responsible for the development of our water system.

I heartily endorse all our Mayor has said. The Board of Commerce is made up of the leaders in our business and civic activities, and we have formed an organization for service, — service to the community, service to the individual, and service to visitors. I, in their behalf, welcome you.

and invite you to use that service in any of our numerous boards or divisions while you are here, one and all, and we trust that that service will be able to make your visit here both pleasant and profitable. And, as our Mayor has said, if we do not live up to it, go to Steve Taylor and ask him why. (Applause.)

Response by President Frank A. Barbour.

The President. Mr. Mayor, Mr. Ritchie: For the Association I thank you for your words of welcome. That these words are to be translated into very tangible hospitality we have ample proof in the program of entertainment which has been prepared. As presiding officer my fear is that the attractions of your city will be so great that our technical sessions may suffer and the serious purpose of this convention be in some measure lost sight of, and we have a very serious purpose in these meetings.

We believe that there is no other public utility entrusted to municipal officers that compares in point of responsibility with the water system. It is possible for a city to live without gas or electricity, or good streets and, for a time, without sewers, but if for any reason the water supply is cut off for a very short period, municipal life is ended. We believe that it is only by associations such as this, that the men in charge of this most important public service can be kept up to the highest efficiency, and that attendance at these conventions is the most direct means of deriving from this Association the best that it has to offer.

I am glad to know that it is the practice in New Bedford to pay the expenses of the department officials to the meetings of this and other associations. In my opinion the well-known efficiency of your department is largely the result of the attendance of such men as Mr. Coggeshall and Mr. Taylor at these meetings, and I think it would be a very wise thing for all cities to follow the course that New Bedford has adopted.

It is thirty-six years since we last met here in New Bedford, but you will credit us with the fact that we came back just as soon as you had the necessary hotel accommodations. There are several reasons why we should meet in New Bedford. The growth of your city during the past twenty years has been one of the outstanding facts in Massachusetts, — and as municipal officers — we are interested in finding out how you have kept step with this growth in your public utilities, and particularly in your water system. There is another reason for our coming here, and that is the hope that Mr. Coggeshall will feel that we are expressing in some measure by our coming the affection and respect that we hold for him.

We note that in the thirty-six years since we were last here — during which time you have grown from a population of somewhat less than forty thousand to somewhat more than one hundred and twenty thousand, you have had one man for Mayor twenty-two years, and I believe that same man has also been chairman of the Water Board. We expect to come

back again, Mr. Mayor, in about twenty years, or perhaps a little less, and I hope that we shall then find you in the same position you occupy to-day.

I again thank you, gentlemen, for coming here and welcoming us to your city, and we hope that it will not be necessary during our stay for us to refer the Police Department to our cordial relations with you.

On motion of Frederic I. Winslow, duly seconded, it was voted that the President shall at some time during the convention appoint a committee of five to bring in at the November meeting a list of nominations for officers for the ensuing year. The President later announced the appointment on this committee of Messrs. Charles W. Sherman, Samuel B. Killam, Frank Emerson, Richard H. Ellis and Thomas E. Lally.

On a motion by Mr. J. M. Diven, duly seconded and amended by Mr. George A. King, to omit the word "alternating" and have it refer to all currents, it was voted to appoint a committee to investigate the grounding of alternating currents on house plumbing, to act in connection with a similar committee of the American Water Works Association.

The following were duly elected members of the Association.

Active: John Brown, Resident Engineer, Fall River, Mass.; Julius W. Bugbee, Superintendent and Chemist, Sewage Disposal Works, Providence, R. I.; Steve C. Burghardt, Manager Water Company, Stockbridge, Mass.; John E. Gleason, Superintendent Water Department, Providence, R. I.; W. S. Lea, Consulting Engineer, Montreal, P. Q.; Alexander H. McDonald, Superintendent Water Department, Littleton, N H.; Joseph W. Money, Superintendent Warwick Water Company, Anthony, R. I.; Chester A. Moore, Consulting Engineer, Somerville, Mass.; Humphrey Sullivan, Foreman Hartford Water Works, Hartford, Conn.; Ellsworth B. Tolman, Assisting Superintendent Water Works, New Bedford, Mass.; John W. Mulcahy, Superintendent Water Works, Braintree, Mass.; Francis H. Nolan, Superintendent Water Works, Avon, Mass.; Richard F. Forrest, Superintendent Water Works, Randolph and Holbrook, Mass.; Edmund Dunn, Mechanical Engineer for Water Commission, Garfield, N. J.; Henry S. Charron, Superintendent Water Works, Burlington, Vt.; Ernest E. Lothrop, Town Manager, Mansfield, Mass.; A. A. Gathemann, Civil Engineer, Hanover, Mass.; Gilbert H. Pratt, Chemist, Belleville, N. J.

Associates: George A. Caldwell & Co., Boston 24; New England Oil Refining Co., Fall River, Mass.; Red Hed Manufacturing Co., 287 Atlantic Avenue, Boston 3, Mass.

Report of Progress of Committee on Standard Specifications for Water Meters.

Mr. Charles W. Sherman. Mr. President, if it is not imposing on the meeting I should like to take a minute to make verbal report of progress for a committee. I am reporting for the Joint Committee on Specifications for Standard Water Meters of this Association and the American Water Works Association. The Chairman on the part of this Association, Mr. Brush, is somewhere around the convention, but I do not think he is here at the moment, and I would therefore report as Chairman of the Joint Committee.

The Convention a year ago accepted the standard specifications which were recommended for disc meters and continued the committee to consider other classes of meters. Good progress is being made and we expect to submit our report in print in the near future, so that it may be considered at one of the winter meetings of this Association and at the next annual convention of the American Association.

On motion of Mr. George A. King, duly seconded, it was voted, That the President be authorized to appoint a committee of Massachusetts members to consider the advisability of united action with the State authorities of Massachusetts on the subject of merging water departments with other departments in management and finance, or either of them.

Award of Dexter Brackett Medal.

Mr. Robert S. Weston. The Committee on the award of the Dexter Brackett Medal, consisting of Messrs. Tighe, Taylor and myself, after having read all the papers presented in last year's Journal, have come to the unanimous conclusion that the paper which merited the medal was one written by the last speaker, Mr. X. H. Goodnough, Chief Engineer of the Massachusetts Department of Health. The paper was on the subject of "Rainfall in New England." That paper, as you know, was not only a presentation of the facts in an interesting way, but it represented twenty years' work, all under his guidance, and initiated by him.

(To Mr. Goodnough.)

I have great pleasure, sir, in presenting this beautiful medal, and I think you will appreciate it more, because you have been so closely identified with the work with which the founder had so much to do. (Applause.)

Mr. Goodnough. I need hardly say that I feel greatly honored at being the recipient of this medal. I knew Mr. Brackett, of course, very well. I was more or less associated with him for a great many years, and especially with Mr. Stearns, who I think was instrumental in getting up

this memorial. I connot conceive of a more satisfactory memorial to Mr. Brackett, who was one of the chief workers for this Association through all of its earlier years.

The work of the Association has really, it seems to me, been a wonderful one. I think that more than any other one thing, the work of this Association has aided in securing the very satisfactory water supplies which we now have practically throughout New England. When Mr. Brackett was first a member of the Association, some thirty years or more ago, we were still using water directly from the Merrimack River and other polluted streams, without any idea that that might be the cause of the typhoid fever which prevailed so extensively in those places. It was to members of this Association that we owed the discovery of a great many of the causes of sickness from water and the means of preventing it; also the practical means of providing a water which is safe and of excellent quality, which we have now generally throughout New England.

I greatly appreciate the honor which you have done me. (Applause.)

Financing of Municipal Water Works.

President Barbour. It is almost impossible under the general laws to finance any improvement of water supplies with bonds running for reasonable terms. The result is that at the present time it is necessary to wait until the Legislature meets and obtain special legislation. Mr. Waddell, the Director of Accounts, has said to me that he would like to have the coöperation of this Association in going before the Legislature and getting some amendments in general legislation. I think perhaps it would be well if Mr. Sherman would state in a few words just what the present condition of the general laws is with regard to municipal finance pertaining to water-works improvements.

Mr. Charles W. Sherman. This is a matter really of considerable importance to us, — in Massachusetts at least.

The present law relating to the financing of municipal water works in Massachusetts is contained in two brief paragraphs of Chapter 719 of the Acts of 1913, and is as follows:

> Section 6. Cities and towns, may incur debt outside the limit of indebtedness prescribed in this act for the following purposes and payable within the periods hereinafter specified: —
>
> (2.) For establishing or purchasing a system for supplying the inhabitants of a city or town with water, or for the purchase of land for the protection of a water system, or for acquiring water rights, thirty years.
>
> (3.) For the extension of water mains and for water departmental equipment, five years.

That is the whole thing, and you will see by this that, outside of a whole new system, five years is the limit of time for which bonds may be issued

for the installation of extensions of the system, or the buying of land for the protection of the supply. That is limited to five years unless you get special legislation. It means that the bonds must be paid within the five years, and in five annual payments. That was promulgated in 1913 and is about the worst ever. The provision is for serial payments.

This struck some of us as so raw that at one time Mr. William S. Johnson, Mr. Symonds and myself presented some discussion of the law to this Association, and followed it up by petitioning the Legislature as individuals for an amendment to the law.

Perhaps I might say that a further point in relation to the serial payment of the bonds requires that the payments shall begin at once and shall be for the whole amount, and that the payment in no year shall be less than that of a succeeding year. You have to pay as much in the first year as you do in any later year, if not more. If the sum is not equally divisible the larger amounts must be paid the earlier years. We presented what we thought was an unanswerable argument, but the best we could get out of the Legislature was that in the construction of new works the first payment might be deferred for a term of three years; thereafter there must be 27 installments to make it up. That does give you a little time to begin to get some money in before you begin to pay it out. Under the original law you must make as large a payment in the first year as in any other.

When we presented that discussion in the Association we got Mr. Waddell, who was then Clerk in the Board of Statistics, to come up and discuss our paper. He could not see our point of view, and he opposed what we wanted in the Legislature. It is therefore a great pleasure to me that he has now come around to see some light in the matter and recognized the interest of this Association in it, and asked the help of the Association to revise the law in some way which will presumably be more satisfactory to water works men and will be more satisfactory to him also.

With that in view I offer the following motion:

Moved that the President be authorized to appoint a committee of three members to confer with Massachusetts officials upon the desirability of a modification of the laws relating to the financing of municipal water-works, and to report their conclusions and recommendations to the Association.

Mr. Caleb M. Saville. That would have to be Massachusetts members.

Mr. Sherman. I did not put it in the motion, but I assume that it would be Massachusetts members. It might be put in the motion.

Mr. X. H. Goodnough. I had hoped something of this sort would be done. The handling of the business has been somewhat elastic, to say the least, by a department which knows nothing whatever, or did know nothing whatever of the water-works business. I think a campaign of

education is sadly needed, and that some judgment should be used in regulating the issue of bonds without trying to bring everything down to a fixed rule. I hope the motion will prevail.

[The motion was duly seconded and carried.]

On motion of Frank A. Marston, duly seconded, it was voted that the thanks of the New England Water Works Association are hereby extended to Hon. W. H. B. Remington, Mayor of New Bedford; to the New Bedford Water Board, and to the other officials and employees of the City; to the members of the Honorary Reception Committee, the Local Committee of Arrangements, the Ladies' Committee, and to all others who have given so generously of their time and means to make this one of the most successful conventions in the history of the Association.

On motion of Mr. J. M. Diven, duly seconded, it was voted: *Resolved*, that the New England Water Works Association, in Annual Convention assembled, hereby extends to Robert C. P. Coggeshall, one of its founders, for many years its secretary and its past president, its sincere sympathy in his illness, and expresses its great regret that it has not been possible for him to be present at its meeting; and renews its expression of esteem and affection, and of appreciation of his great service to the Association.

On motion of Frank J. Gifford, duly seconded, it was voted that the thanks of the New England Water Works Association are hereby extended to the Water Works Manufacturers Association, and to the members of its committees, who have contributed so much to the success of this, the forty-first annual convention.

(*Adjourned.*)

New England Water Works Association

ORGANIZED 1882.

Vol. XXXVI. December, 1922. No. 4.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

BOSTON HIGH PRESSURE FIRE SYSTEM AND GENERAL PROBLEM OF SPECIAL FIRE SERVICE.

BY FRANK A. MCINNES.*

[September 13, 1922.]

The Boston high pressure fire system, as now proposed, will protect approximately one square mile of territory covering practically the entire congested value district of the city. It will consist of eight pumping units in three separate stations with 19 miles of mains. It is designed to operate, if the necessity should arise, at a pressure of 300 lb. to the square inch.

Two stations with four pumping units, 11.75 miles of mains and 313 hydrants have been in service for the past seven months, furnishing approximately two thirds the measure of protection which the completed system will afford.

A description of the existing system follows: —

PUMPING STATION NO. 1.

Located in a fireproof isolated area, in the basement of the Lincoln Power Station of the Boston Elevated Railway Co., corner of Commercial and Battery Streets; fire hazard very slight.

Equipment includes two Worthington 3-stage double suction centrifugal pumps, each direct connected to a Westinghouse 750 h.p. steam turbine of the horizontal impulse type, operating at 1 165 r.p.m. with steam pressure of 175 lb., atmospheric exhaust.

Two 16-in. suction mains, both connecting with low service distribution system of city (pressure 50 to 60 lb.) one of them also connecting with high service distribution system (pressure 85 to 90 lb.). One 16-in. suction main, connecting with large intake conduit supplying salt water from harbor to Boston Elevated power station for condensing purposes, provides an emergency salt water supply. Two 16-in. discharge mains, each equipped with a Venturi meter, extend from the station to the H. P. F. distribution system. A centrifugal vacuum pump, with 75 gal. priming

* Division Engineer, Water Division, Public Works Department, Boston, Mass.

tank, driven by a 10 h.p. 220 volt D. C. motor is provided to prime the fire pumps when suction is taken from salt water.

A vertical centrifugal single stage sump pump, driven by a 220 volt D.C. motor, takes care of any leakage, etc., within the station.

The water piping is of cast-iron with flanged joints, each piece of pipe in force main being separately tested at a pressure of 600 lb. per sq. in. before being assembled. A 4-in. by-pass between suction and discharge piping equipped with the necessary check valves and meter, insures the absence of air in the system and provides means for measuring the leakage.

The principal control valves on the piping system are electrically operated by Deane Control. Ross regulating valves are installed between the suction and discharge of each pump by means of which the pressures at the pumps are controlled from the operating board, upon which the necessary gages and indicators are installed and from which the valves in the piping system, the vacuum pump and the sump pump are operated.

The turbines are started by hand throttle. Steam is supplied through an 8-in. loop pipe connecting to each end of steam header in the boiler room of the Boston Elevated station, where a battery of twenty (20) Babcock and Wilcox boilers with a total of 10 344 h.p. are located, eight to ten of these boilers being always in service.

At an acceptance test made on December 9, 1921, by the National Board of Fire Underwriters, Pump No. 1 discharged 3 100 gal. per min. at 301 lb. pressure and 4 676 gal. per min. at 201 lb. pressure. Pump No. 2 discharged 3 114 gal. per min. at 300 lb. pressure; 5 164 gal. per min. at 209 lb. pressure and 7 400 gal. per min. at 100 lb. pressure. The two pumps together discharged 6 580 gal. per min. at 292 lb. pressure and 10 266 gal. per min. at 201 lb. pressure. The above performance easily fulfilled the contract requirements.

Pumping Station No. 2.

Located in a fireproof building, constructed for the purpose, within the boiler room of the third station of the Edison Electric Illuminating Co. on Atlantic Avenue, opposite Pearl Street; fire hazard very slight.

The equipment includes two Worthington 4-stage single suction centrifugal pumps, each direct connected through semi-flexible couplings, to Westinghouse 750 h.p. 235 volt D.C. shunt wound interpole motor with a speed range from 860 to 1 050 r.p.m.

Two 16-in. suction mains both connecting with low service distribution system of city (pressure 50 to 60 lb.) one of them also connecting with high service distribution system of city (pressure 85 to 90 lb.). One 16-in. suction main, connecting with large intake conduit supplying condensing water for the Edison station, provides an emergency salt water supply.

Two 16-in. discharge mains, each equipped with a Venturi meter, extend from the station to the H. P. F. distribution system. Two cen-

trifugal vacuum pumps with a 75 gal. priming tank, each driven by 10 h.p. motor, are provided for priming the fire pumps when suction is taken from salt water. One vertical centrifugal single stage motor driven sump pump takes care of any leakage, etc., within the station.

The water piping is of cast-iron with flanged joints, each piece of pipe in force main being separately tested at a pressure of 600 lb. per sq. in. before being assembled. A 2-in. by-pass between suction and discharge piping equipped with the necessary check valves and meter, insures the absence of air in the system and provides means for measuring the leakage.

The principal control valves on the piping systems are electrically operated by Deane control. Ross regulating valves are installed between the suction and discharge of each pump by means of which the pressures at the pumps are controlled.

The switchboard consists of two separate units; one board, designed to handle the heavy starting and running current required for the main motor, contains the connections from the Edison power lines, the bus bars and the secondary contactors for operating the motors. The other, or main control board, consists of four panels — one for each motor, one for the station auxiliaries, and one for the fire alarm. Each motor panel is equipped with drum master switches for operating the main motor, control switches for motor operated valves, gages to indicate suction and discharge pressure, ammeter to indicate amount of current required by motor and wattmeter to register total power required by motor.

In putting a pumping unit into service it is necessary to turn one, two or three master switches, depending upon which suction and discharge mains are to be operated; one master switch only is required to bring motor up to speed, the delivering of water and its pressure being determined by operation of a motor field rheostat and the Ross regulating valve; the control of the latter is through a hand valve immediately in front of each motor panel; the actual position of the regulating valve being shown at all times on a dial visible from the operating platform. Two Venturi meters which register the water pumped into each discharge main, are located immediately beside the control board.

The above arrangement makes it possible for one man to operate easily and quickly the entire equipment in the station. Under normal conditions fire pressure is available within 40 sec. after an alarm is received.

In the event of failure of the fresh water suction supply, the pumps can be primed and ready for service with salt water, in less than three minutes time.

Power for operating the pumps is furnished through cables extending to the pump room from the main switchboard in the generating room of the Edison third station in which are located four 1 600 k.w. and two 800 k.w. direct current generators, and four 1 000 k.w. and one 500 k.w. motor generators. The direct current generators are operated by engines

supplied with steam from a battery of nineteen (19) boilers of 8 400 h.p. capacity, six to ten of the boilers being always under steam. The motor generators receive current at 6 600 volts A. C. from the main station of the Edison Co. in South Boston, delivering it at 250 volts D.C. Three underground transmission lines extend, over two separate routes, to the Edison third station, any two of which have sufficient capacity to operate the entire motor generator installation in the station. Ten direct current tie lines from seven sub-stations in the city are available, on an emergency, to supply 1 500 to 1 800 k.w. to the Edison third station. In addition, two storage batteries with a combined capacity of 9 470 ampere hours, sufficient to run both fire pumps for a period of approximately two hours, are available at the Edison third station.

At a test recently made by the National Board of Fire Underwriters, Pump No. 1 discharged 3 141 gal. per min. at 298-lb. pressure and 4 413 gal. per min. at 202-lb. pressure. Pump No. 2 discharged 3 000 gal. per min. at 300-lb. pressure and 4 407 gal. per min. at 200-lb. pressure. The two pumps operating together discharged 6 580 gal. per min. at 292-lb. pressure. The above performance easily fulfilled the contract requirements.

Distribution System.

The system was designed to deliver 12 000 gal. per min. about any block with a hydrant pressure of 250 lb. per sq. in., and a pump pressure of 300 lb. per sq. in. As a matter of fact, the efficiency of the system exceeds this requirement as during construction the sizes of mains were increased in several instances to provide for different proposed locations of pumping stations. One hydrant is allowed for each 40 000 sq. ft. of area; to secure this distribution, a tracing of the pipe system was superimposed on a sheet of cross section paper in which each square represented 40 000 sq. ft. In this way a sufficient number of hydrants were located to fulfill the requirement.

The system is so designed that, when completed, it will be operated under normal conditions in two parts overlapping each other, or as a duplicate system. This arrangement calls for slightly larger mains, but greatly increases the efficiency in the event of a broken main or hydrant; in such a case, one system would be at once shut off at the pumping station and would remain out of service until the gates required to control the break had been closed, the other system continuing to function at full power; in other words, approximately one half the hydrants would remain in service despite a break in the system.

The system now consists of —

20 140 lin. ft. 20-in. pipe, 1.51 in. thick.
28 808 lin. ft. 16-in. pipe, 1.27 in. thick.
13 081 lin. ft. 12-in. pipe, 1.04 in. thick.

with 313 hydrants supplied by 8-in. pipe 0.8-in. thick.

The straight pipe and special castings are cast-iron excepting branches where the opening from the run is 12 in. or over, in which case semi-steel is used. All pipes were subjected to a hammer test at a pressure of 500 lb. per sq. in.

Two lead grooves are cast in bell end and two in spigot end of each pipe. If it is necessary, during installation of system, to cut a pipe, two lead grooves are required in their proper location near the end of the cut pipe.

The joint material used where unbalanced pressures exist, or might develop, is an alloy of 95 per cent. lead and 5 per cent. tin. Extensive preliminary tests showed that the admixture of tin increased the strength of the joint sufficiently to safely permit tie rods to be dispensed with; a conclusion that has been verified in practice. The joints were made as follows: —

A small pouring pot is kept warm floating in a larger kettle of hot lead; when the joint is to be made, sufficient lead is measured into the small pot and the necessary amount of block tin is added at the last minute. The caulking is done with dog tools using a two handed 4-lb. hammer, a starting chisel and three sets of caulking chisels. The joint is finished or polished off with hand tools.

The mains, in order to avoid as far as possible interference with sewer drains and water services, were laid at a normal depth of 5.5 ft. from the surface of the street to top of barrel of pipe — they were all tested, before joints were covered, for a period of one hour at a pressure of 400 lb. per sq. in. For several years past no difficulty has been experienced in keeping the joint leakage below one half gal. per lin. ft. of pipe joint per 24 hours; in fact, there is usually no leakage of this kind. It is however, impossible to avoid some loss of water at gates and hydrants, and the contract test requirement adopted of 2 gal. leakage per lin. ft. of joint in 24 hours is as small as is practicable.

The post hydrant used was designed and patented by Joseph A. Rourke, now Commissioner of Public Works of Boston. It is of rugged design with $8\frac{1}{2}$-in. barrel $6\frac{1}{4}$-in. main valve, opening against the pressure, and four $2\frac{1}{2}$-in. independently controlled outlets. A notable feature of the design is an auxiliary valve formed by three way cock operated by a covered stem extending along the side of the barrel and terminating in an operating nut at the head of the hydrant. One position of the three way cock closes the waste and equalizes the pressure above and below the main valve in hydrant barrel, the other position opens the waste and closes the connection with hydrant barrel. The hydrant was designed for a normal delivery of 2 000 gal. per min., the loss at this flow being less than 8 lb.

The valves, designed by the department, are of the solid wedge type, bronze mounted, bodies and bonnets of semi-steel of 30 000 lb. tensile strength. All stems are of monel metal, tensile strength 80 000 lb. per sq. in. Each gate was tested for strength at 500 lb. per sq. in., for leakage at 450 lb. per sq. in., and for operation at 300 lb. per sq. in.

Signal System.

Alarms are received in the pumping stations on the usual tapper and gong circuits of the Fire Department alarm system with a perforating register and small gong on the tapper circuit and gong on the gong circuit. For signalling from fires, two special circuits connecting telephone jacks in fire alarm boxes in high pressure fire zone to a Morse key, telephone jack and relay at fire alarm headquarters; the relays operate registers, time stamps, flash lights and sounders. Portable telegraph and telephone instruments, carried by chief officers responding in high pressure districts, are used for code signals for increase or decrease in pressure; these are repeated over a special alarm circuit connecting fire alarm headquarters with both stations; Morse keys and relays operating perforating registers and red flash light are provided at headquarters and each station; headquarters has a tapper and time stamp and each station an 8-in. turtle gong. Orders from one station to the other for the operation of additional pumps are transmitted directly over this circuit. Fire alarm switchboards in the pumping stations are of slate, with metal mountings; standard fire station keys and switches provide testing facilities on each board. A single telephone line connects the Fire Department telephone switchboard in headquarters with both stations.

All orders are transmitted by telegraph, using special code signals for purposes of record; telephones are used only for confirmation. Signals repeated back for verification.

The system is operated by the Fire Department, the distribution system only being maintained by the Public Works Department.

The two pumping plants complete were furnished and installed by the Westinghouse Elec. & Mfg. Co., George S. Gibbs, Boston representative.

General Problem of Special Fire Service.

A well designed and properly installed H. P. F. system is an invaluable weapon of defense against fire, its notable characteristics being power and dependability.

At times, a simple wooden club may suffice to maintain order; again, a revolver is necessary to effect the same purpose, and again a gatling gun must be called into service to avoid disaster; so in fire fighting, the time is sure to come when the special fire system, like the gatling gun, is indispensable if the fire demon is to be held in check. The ability to furnish a sufficient number of large and uniformly powerful streams, in other words, the power to make every blow a hard blow, is one outstanding advantage of such a system. This does not mean that high pressure must always be carried, but simply that the required volume of water at the necessary pressure is quickly and surely available; in New York 125-lb. pump pressure has been found to be sufficient in approximately 90 per cent. of the fires; in one instance only has 225 lb. been found necessary.

In Boston, during the eight months the system has been in service, 125-lb. pump pressure has not yet been exceeded in approximately 100 fires, none of them, happily, being serious. If the mains of the distribution system are of ample size, the name "high pressures" will prove a misnomer, except in the case of multiple serious fires or of a train of adverse circumstances resulting in a threatened conflagration. When unusual danger threatens, the power is available and under other and normal conditions the system functions most effectively, as a flood of water through large nozzles at a uniform pressure can be very quickly made available.

A second outstanding advantage is the fact that no connections other than those to hydrants are taken, or at least should be taken, from the mains of the system; with the result that *the demands upon it are only those made by the firemen* who know its limitations, and it can be depended upon to function with full power under all conditions. The importance of this feature is apparent when the following story of three recent conflagrations is told.

In Baltimore, 1904, water was found to be flowing to waste more or less freely when the fire was under control, through the following pipes: —

50 — 3-in., 4-in., 6-in. fire pipes,
89 — 3-in., 4-in., 6-in. elevator pipes,
6 — 6-in. service pipes,
29 — 4-in. service pipes,
108 — 3-in. service pipes,
39 — 2-in. service pipes,
24 — 1½-in. service pipes,
52 — 1-in. service pipes.

In Chelsea, 1908, despite an heroic effort to shut off all connections from the distribution system in advance of the fire, a careful estimate shows that approximately 6 700 gal. per min. were flowing to waste and destroying pressure at the height of the fire.

In Salem, 1914, two 4-in. and one 6-in. pipes were wasting approximately 7 200 gal. per min. within 40 min. after the fire started. In addition, one 8-in., six 6-in. and two 4-in. pipes were discharging into broken inside equipment before the fire was under control.

In the three above mentioned cases the inevitable happened; the work of the firemen being fatally handicapped by lack of water due to waste from broken connections, the amount of which, in each case, at least equalled the volume of water delivered on the fire.

While direct permanent connections other than to hydrants are taboo, yet hose connections from hydrants to outside pipes supplying sprinkler systems and standpipes within buildings are of the greatest possible value. This fact has not been properly appreciated, at least as far as its practical application goes. It will be conceded that water from a sprinkler system is more apt to reach the seat of fire than are streams

directed from the outside; why then is it not sane and logical to require that a connection, equipped with pressure gage, be made to the sprinkler system at the outset of a fire, to be used if the pressure on the inside system falls too low for effective service, the sprinkler system, of course, being permanently equipped with the necessary check valves.

The connections from distribution systems are rapidly growing in number and size, due to the increasing demand for sprinkler protection and to the requirements of modern plumbing. The danger of destruction of hydrant service at time of fire must also increase, and the time is not far distant when the high pressure fire system will be considered a necessity in all locations where values are high and buildings congested. It constitutes the best insurance against conflagration yet devised.

With the belief that the opinions of men who actually "chew smoke" in the operation of special fire systems will prove valuable and interesting, the following is submitted: —

Chief John O. Taber of Boston writes: —

"The immense aggregation of values in the buildings and their contents in the business district of Boston, and the possibility of conflagrations, with tremendous losses which effect disastrous results on business and civic growth, are striking arguments in favor of providing the most effective known means of preventing such catastrophies. The structural conditions existant in our city, the occupancies, and other features, tend to produce a high conflagration hazard, particularly in sections which are crowded and poorly accessible. Taken as a whole, the chances for sweeping fires in large cities are considerable, even though the Fire Department be efficient and well maintained. All that is required under certain conditions is the right combination of circumstances to make a fire too large for a department to handle. We had such a combination of circumstances in Boston on August 9, 1910. We have had many more since then in which we have been lucky. Pure luck, that's all.

"With the high pressure system in service, the mains are well looped in sufficient areas, with an ample supply of hydrants in which service will not be affected by the breaking of connections inside buildings, thereby bleeding the system. It has been the tendency in modern fire-fighting to use large penetrating streams, and these alone are effective on a fire, well under way, in the ordinary large area buildings filled with combustible stock. Engine supplies at the present time are not capable of alone furnishing the necessary volume through one of our large nozzles, while one hydrant on a high pressure system will supply four or five such streams.

"To sum up the advantages of the high pressure fire system it means that a large number of powerful streams can be concentrated upon a fire in a much shorter space of time with fewer men and less apparatus than fire engines, and at the same time the protection of the rest of the city would not be weakened to the extent now necessary on multiple alarms from the district covered by the high pressure system. It will deliver its full capacity at any point in the district covered at any desired pressure, and can sustain this pressure indefinitely. It eliminates the confusion entailed in the operation of a large number of fire engines. It further tends to prevent a misunderstanding of orders, and in every manner

simplifies operation. Above all, it provides protection to the high-value district from which about all of our sources, supplies and revenue emanate. It is the greatest insurance against conflagration. It forms an effective barrier against fires starting outside the district, and offers the most efficient check in the district, which might otherwise involve a number of large blocks.

"We have used the H. P. F. system for eight months past, at approximately 100 fires. On arrival at the scene of fire we have found in all cases 125-lb. pressure ready and the service has been 100 per cent. I am satisfied that the use of the system has been such as to stop many of the fires in their incipiency, preventing greater loss than would have resulted without it.

"I go on record as being unqualifiedly in favor of the completion of the present high pressure system."

Asst. Chief Joseph B. Martin of New York City writes: —

"I beg leave to state that the high pressure water distributing system is one which admits of very broad consideration and, in my opinion, considering the highly commendable and efficient result, which stands out paramount on every occasion that the high pressure system has been employed in New York City, one is safely empowered if he refers to it as being the greatest, most efficient and most substantial auxiliary unit for fire-fighting purposes ever employed or installed.

"The extensive fires and conflagrations up to and previous to the year 1904 in many large American cities caused the officials, and among them, New York, to view with alarm the possibility of a repetition of these fires and emphasized the necessity of installing ways and means of protection against such a calamity. The result was the preparation of plans for the introduction of the high pressure service, which was inaugurated in 1904, and completely installed and ready for service in 1908.

"The first high pressure system in Greater New York, installed at Coney Island, demonstrated its value in July, 1908, when it was the dominant factor in extinguishing a conflagration which would, no doubt, have reduced the almost complete frame building construction there to ashes.

"The constant, unvarying efficiency demonstrated by this high pressure system enables and prompts me to highly recommend and urge its installation in any city where water facilities are available and accessible, and while the primary cost of installation is high in a city like New York, magnificent results are embodied in its readiness for immediate use, accessibility for connecting lines of hose to outlets, excellent water delivery and pressure control by independent valves, the simplicity of operation, elimination of smoke as from steam pumpers, ability to operate four or five lines from one hydrant. All of these facts enable me, from my practical association and observance of the high pressure system operation, to highly commend and recommend its adoption as the paramount factor in auxiliary fire extinguishing equipment.

"Another reference that highly commends the efficiency of the high pressure installation is the fact that the district charges imposed by the underwriters were modified and reduced upon risks in buildings and contents located in the high pressure districts.

"And when I recall the night of January 9, 1909, when three very extensive and threatening fires took place at almost the same time, and

all in the high pressure district — fourth alarm, station 122, Hudson and Franklin Sts.; third alarm, station 169, Grand St. and Bowery; fifth alarm, station 265, Broadway and Bleecker St. The pressure at the pumping stations was raised to 225 lb. and it was estimated that 15 000 000 gal. of water was delivered through seventy lines of hose, and it was unanimously agreed that the high pressure had saved the borough of Manhattan from a record conflagration, and I positively verify and corroborate this statement.

"At the Equitable Building fire in 1912, the high pressure system had not been extended to this locality at that time, being only installed as far as Maiden Lane, several blocks north of the Equitable Building, but several 3-in. lines were stretched and even at this distance did very effective work.

"At another serious and extensive fire on 25th St., between 11th and 12th Ave., many 3-in. lines were stretched from the then northern boundary of the high pressure system which extended at that time north only as far as 23rd St. Its operation here was credited with effectively controlling the area of fire on that side.

"And so on through a long list of fires which were controlled and held and checked by the first alarm assignment — four engines, two trucks and a water tower — operating at times as many as eleven and twelve effective streams at a fire which would ordinarily call for a third alarm assignment if the locality was not within the high pressure zone and the excellent water delivery available.

"I respectfully refer also to the recent fire at 110–114 Jane St., where several explosions and falling walls presented a very threatening and dangerous situation. This warehouse extends through from Jane St. to West 12th St.; a very extensive area, and when explosions took place the falling walls almost demolished adjoining residence buildings, and required the use of fifty lines of hose with effective streams from each with pressures of 125 lb. at the start at the pumping station, which I ordered increased first to 150 lb. and then to 175 lb. This excellent pressure was maintained uninterruptedly for nine hours when the fire was under control and not a break was suffered with this exceptional demand on the six pumps which were used in the pumping stations.

"And so on through a long list of fires at which the high pressure water delivery has been used since 1908, there is the one sentiment, and that is unanimous, that it deserves the highest commendation and the most commendable references that can be awarded to any auxiliary fire extinguishing system in existence."

Chief Ross B. Davis, Philadelphia, writes: —

"The many advantages attached to a high pressure system are numerous and can be appreciated all the more after experiencing so many years without one.

"The disastrous conditions and possibly a conflagration may be avoided by the immediate use of the high pressure lines. Some fires gain such headway before arrival of apparatus that it is impossible to get within reach of them without a high pressure stream; especially where the fire reaches such a degree of heat that the surrounding property is instantaneously ignited.

"I recall a large fire happened in the month of February, 1921, which was a four-story brick building with a 200-ft. frontage on a street 80 ft.

wide. The wind was blowing at about the rate of 22 miles an hour down this street. Notwithstanding the direction of the wind, the nature of the contents in this building generated heat to such a degree as to set fire to several buildings across the street, placing our men in a very hazardous position.

"Many fires in upper floors of high buildings can be held and heat waves broken by high pressure lines until you can get your lines in action on the floors where the fire is burning. Extreme caution must be used in handling these lines and especially in the loading of buildings with the weight of water, particularly when working lines in buildings.

"The installation of the high pressure system is invaluable to any city or town and may in time be the means of doing away with the pumping unit in the Fire Departments, which may prove to be more economical.

"The high pressure system, which has been installed to date, has performed such excellent service and has been such a gratifying success that I can not urge too strongly the installation of such system to cover an entire city."

Chief L. H. Elling, Toledo, O., writes: —

"As a Fire Department auxiliary it has proven its great value by permitting the rapid concentration of a large number of powerful streams within the area served, and, by lessening the number of fire engines required to do this, increases the efficiency of the fire service in other parts of the city in case of a second fire.

"The system has fulfilled our fondest expectations whenever we found it necessary to use same in the way of getting plenty of water, at any desired pressure, through short lines of hose, which has enabled us to confine all large fires in the congested district to their place of origin.

"On several occasions we found it necessary to use more water than our combined fire engines could furnish and as the high pressure system uses raw water, it saves the low pressure system that much filtration.

"The system is giving such good service in the territory covered that, in my opinion, it should be extended so that others would receive the benefits from same."

Chief William Russell, Toronto, Canada, writes: —

"I consider such means of combatting fires the most valuable acquisition obtainable and would advocate all large cities installing such protection, expensive as it may be in the beginning. I venture to say that such a plant would repay any large city in no time. I have used ours very effectively at different times and would hate to assume my present responsibility without it to fall back on."

Chief August Emrich, Baltimore, Md., writes: —

"I have to say that the important points in connection with the Baltimore system are as follows: —

"The installation of a steam plant in connection with horizontal, Corliss, twin simple, non-condensing, crank and fly wheel types of pumps.

"The use of all lap-welded, soft, open hearth steel pipe, together with a universal joint designed without gaskets, and which thereby prevents leakage on the system.

"The use of portable hydrants of the type used here makes it possible to take off of any one of four lines any pressure as may be desired, not exceeding the pressure, of course, carried on the main at the time.

"I have no hesitancy in saying that I do not think that a more modern type of high pressure system exists than as installed in the city of Baltimore, and when I say, and as I have shown you, that when pressure of 75 lb. maintained on the line can be raised to 250 lbs. in from 20 to 22 sec. and kept so for the heaviest fire service, I am of the impression that a more practical system for the extinguishment of fires is not in existence.

"The installation of high pressure systems to prevent conflagrations and for the extinguishment of fires in large cities is indispensable, and affords, in my opinion, the most modern method of fire extinguishment possible at this time."

Chief Thomas R. Murphy, San Francisco, writes: —

"San Francisco's high pressure fire system has been constructed as an auxiliary fire fighting system, following the failure of the domestic water supply system after the earthquake of 1906, and as such, it has so far fulfilled every expectation.

"As its name implies, it is not intended to be used as a primary fire fighting force, or to eliminate pumping engines in the department, owing to the fact that its mains cover only certain sections of the city, and its hydrants are in many cases set too far apart for efficient service, but for its real purpose, viz. the reinforcement of the domestic water supply system, it has at very many occasions proved of very great value.

"With 10 500 000 gal. of water stored at an elevation 758 ft. above city base, practically at the geographical center of the city, and delivered by gravity (normally through two zone tanks acting as pressure reducers, but capable of being delivered at a pressure of over 300 lbs. per sq. in. in the down town and congested value districts), its superiority over the domestic supply system as a factor in controlling large fires, can readily be seen.

"Whether or not a high pressure system is indispensable, should of course largely depend upon local conditions and the capacity of the domestic supply system, as far as San Francisco is concerned, the fire of 1906 has demonstrated the inadequacy of its domestic system and for safety, the high pressure system is absolutely indispensable.

"Ever since its completion, some nine years ago, the local high pressure system has been used at every large fire as far as its mains extend, and in every instance has given complete satisfaction."

The accompanying insert sheet gives a list of the existing H. P. F. and auxiliary fire systems in the United States and Canada, with data concerning the principal features of each system. The somewhat wide divergence of design, due in part to local conditions, is notable.

HIGH PRESSURE FIRE AND AUXILIARY FIRE SYSTEMS IN THE UNITED STATES AND CANADA.

City.	Population U. S Census 1920.	Date of Installation	Type of Power	Gals per Minute	Maximum Pressure Pounds.	Lin Feet of Mains	Sizes of Mains in Inches.	Type of Mains.	No. of Hydrants.	Type of Hydrants.	Suction Supplies.	Cost of System.	No of Acres	Cost per Acre
Atlantic City	50 707	Partly in Service.	Connections to hotel pumps	10 000	To Cover Board Walk District.									
Baltimore	733 826	1912	1 Station, 3 Allis-Chalmers horizontal Corliss, twin simple, non-condensing, crank and fly wheel pumps; 1 Epping Carpenter, horizontal, duplex, direct acting, compound non-condensing (1 000 g.p.m.) pump; 3 Edgmoor water tube boilers, 1 160 h.p. each.	13 000	250	46 700	10–24	Lap welded soft, open, hearth steel with special universal joint.	226	Flush with Ross portable service head.	One from distribution system. One from salt water.	$534 050*	230	$2 300*
Boston	748 060	1921	No. 1 Station, 2 Worthington 3-stage double suction centrifugal pumps direct connected to Westinghouse 750 h.p. steam turbine, horizontal impulse type, 1 165 r.p.m., steam pressure 175 pounds, atmospheric exhaust. No. 2 Station, 2 Worthington 4-stage, single suction, centrifugal pumps, direct connected to Westinghouse 750 h.p. 235-volt, D. C. shunt wound interpole motor, 860 to 1 050 r.p.m.	12 000 18 000	300 200	62 029	12–20	Cast iron double lead groove in bell and spigot, special joint alloy.	313	Post Compression Independent Gates.	Two from distribution system, one from salt water, in each station.	1 370 000	480 approximate	2 854
Brooklyn	2,018 356	1908	No 1 Station, five Worthington 5-stage, horizontal, centrifugal pumps driven by General Electric 800 h.p., 6 600-volt, induction motors. No. 2 Station, three units of same type and capacity.	24 000 40 000	300 200		12–20	Cast iron double lead groove in bell and spigot.		Post Compression Independent Gates.	Two from distribution system.	1 384 500	1 420	975
Buffalo	506 775	Installation in Progress.	1 Station, three 4-stage, centrifugal pumps, 1 500 r p m, driven by three 750-h p. Terry steam turbines, 3 170 r p m, steam pressure 225 pounds, speed reduction by set of herring bone spur gears, running in oil.	9 000	300		12–20	Cast iron with "Universal" machined bolted joints.		Post Compression Independent Gates.			.	
Cincinnati	401 247	1917	Gravity† ..	10 000	150		8–20							.
Cleveland	796 841	1907	1 Station, motor-driven centrifugal pumps . .	12 000	270	37 665	8–20					170 000*	338	500*
Coney Island	. .	1905–6	1 Station, 3 Gould triplex pumps driven by Nash gas engines.	3 600	150		8–16					90 000	147	612
Detroit .. .	993 678	Installation in Progress.	1 Station, six 4-stage centrifugal pumps driven by 700 h.p. motors.	15 000	300	62 099	8–20	Cast iron bell and spigot.	270	Post Compression Independent Gates.				
Fitchburg	41 029	.	Gravity†	5 000	180	28 250	8–16					50 000	346	144
Fort Worth	106 482	1910	1 Steam Station, emergency connection to Distribution System.	5 000	100 to 200	42 200	8–16		106				245	..
Jacksonville .	91 558	1911	1 Station, motor-driven centrifugal pumps	5 000	175 to 192	22 688	8–20		90			58 000	180	537
Lawrence .	94 270	1906	Gravity†	3 000	134	10 200	10–12		30				120	.
Newark	414 524	1905	Gravity†	3 500	160	15 000	20–30		52			135 000	303	446
New York Manhattan	2 284 103	1908	2 Stations, each equipped with 6 Allis-Chalmers 5-stage, centrifugal pumps, direct connected to Allis-Chalmers 800-h p, 6 600-volt, 3-phase, 25-cycle, induction motors, 740 to 750 r p.m.	36 000 60 000	300 200	289 500	12–24	Cast iron double lead groove in bell and spigot.	1 200	Post Compression Independent Gates.	Two from distribution system. One from salt water.	3 280 000* 3 950 400	1 430	2 300* 2 763
Miami	29 571	1913	2 Stations, motor-driven centrifugal and steam pumps	5 500	175	7 450	8–16		20				136	.
Oakland	216 261	1910	Oil engines geared to centrifugal pumps	2 000	200	12 000	10–14					146 000		
Philadelphia	1 823 779	1903 1910	No 1 Station, 7 Deane, vertical, triplex, double-acting pumps, 1 200 g p m; each driven by 3-cylinder, 4-cycle, vertical, 300-h.p., Westinghouse gas engine; 2 pumps of same type, 350 g p m, each driven by 125-h p. gas engine No 2 Station, 10 Deane, vertical, triplex, double-acting, pumps, 1 200 g p m each; 1 pump of same type 350 g p m.; all driven by nine 550-h p and one 125-h p Westinghouse gas engines, same type as No. 1 Station	9 100 12 350	300 300	85 008 163 680	8–20 8–20	Cast iron with flanged bolted joints. Cast iron with Universal machined bolted joints	289 600	Gate valve and Post Compression. Post Compression with Independent Gates.	From Delaware River. From reservoir of 5,000,000 fed by City service.	3 030 000*	512	1 150*
Providence	237 595	1897	Gravity†	7 000	116	29 400	12–24	Cast iron two lead grooves in bell	89	Flush	From City Reservoir.	143 136	358	400
Rochester	295 750	1874	No. 1 Station, 2 steam pumps, one 2-stage, centrifugal pump driven by steam turbine. No. 2 Station, motor-driven, 3-stage, centrifugal pump.	9 000	110	102 960	4–20	Cast iron bell and spigot.						
San Francisco	506 676	1912	Gravity. 10 500 000-gal reservoir with 2 pumping stations in reserve equipped with 8 Byron-Jackson 4-stage centrifugal pumps, direct connected to Curtis 750-h p, horizontal, non-condensing steam turbine, 250-h p. Babcock and Wilcox boilers.	32 000	300	508 000	10–20	Cast iron two lead grooves in bell		Post Compression	Reservoir and San Francisco Bay.		5 300	
Toledo	243 164	1917	1 Station, four 5-stage, horizontal, centrifugal pumps, direct connected to 550-h p, 3-phase, 25-cycle, 4 000-volt motors	8 000	300	22 625	10–16	Cast iron bell and spigot.	66	Post Compression Independent Gates	Two intakes from Maumee River.		140	
Toronto	515 000	1909	1 Station, 2 McDugall, 2-stage, centrifugal pumps, direct connected to Westinghouse Parsons 1 500-h p. condensing, multiple stage, impulse type, steeam turbines.	8 333	300	40 770	6–20	Cast iron bell and spigot	146	Post Compression Independent Gates.	Two intakes from Toronto Bay.	500 000	287	1 742
Winnipeg	178 304	1907–8	1 Station, six triplex, double-acting pumps driven by 4 Crossley, 2-cylinder, tandem, gas engines, 540 h.p each; 2 Crossley, 2-cylinder, tandem, gas engines, 250 h p. each, one producer gas plant consisting of 2 Crossley type producers, 500-h.p each and 2 of 1 000 h p each; city gas also available. Two motor-driven centrifugal pumps	10 800 4 320	300 150	15 840	8–20	Cast iron with double lead grooves bell.		Post Compression Independent Gates.	Intake from Red River	650 000	275	2 364
Worcester .	179 754	..	Gravity† . .	5 000	165	100 320	8–30	Cast iron.		Post.	.		1 380	.

* Exclusive of pumping station and equipment.
† System consists of extension of pipes from High Service into area covered by Low Service.

HIGH PRESSURE FIRE SYSTEMS FROM THE UNDERWRITERS' VIEWPOINT.

G. W. BOOTH*

[*Read September 15th, 1922, at New Bedford, Mass.*]

Losses resulting from conflagrations are those most dreaded by the insurance companies; they correspond in fire insurance to what a wide-spread attack of the plague would be to life insurance. It was following the Baltimore conflagration in 1904 that the National Board of Fire Underwriters organized the Committee of Twenty, superseded two years later by a standing Committee on Fire Prevention, one of the principal functions of which had been to advise on means whereby conflagrations might be averted. The Baltimore High Pressure System was installed as a result of the experience in combating the 1904 Conflagration in that city, and the San Francisco System correspondingly after the 1906 Conflagration,

Conflagrations spread either by the generation of a heat wave of such intensity that everything combustible in its path is involved, or by means of flying brands carried by the wind far in advance of the origin of the fire and setting fire to combustible roofs or porches. The first type of conflagration is that of which we must think in considering the installation of High Pressure Fire Systems, since most of them occur in high value congested districts and it is only in such districts that the expense of installing and maintaining a separate fire main system can be warranted. There is of course much doubt as to whether such a system or any other fire fighting facility will enable a fire department to make a direct stop of a conflagration well started; probably not, since the heat wave is so intense for some distance in advance of the fire as to prohibit a stand. But it will at least facilitate a narrowing and checking of the fire at strategic points, and should serve to prevent a threatening fire from assuming conflagration proportions, as it has in fact been reported as doing in one or more cases in Baltimore.

An inspection of the list of cities in which separate fire main systems have been installed shows that 9 out of the 18 cities which have installed such systems with special pumping stations to supply them have a population in excess of 400 000; four of the other 9 are in excess of 200 000 and most of the others either present special fire protection problems or were able to take advantage of favorable conditions to minimize the cost of installation, or of maintenance, or both. In this comparison are not included

* Chief Engineer, National Board of Fire Underwriters, New York City.

those cities which have made extensions of the domestic high service systems into congested value sections at lower elevations. Such extensions have been made in Worcester, Providence, Newark, N. J., Fitchburg, Lawrence, and a few other cities, and furnishing from 3 000 to 8 000 gal. per minute at initial pressures ranging from 130 to 180 lb. must be considered as highly valuable auxiliaries to other fire-fighting facilities.

An interesting form of development is that in Atlantic City, where the high value hotel district is protected in part by a system of mains and hydrants installed by the city, with supply from the fire pumps in each of the hotels under protection. A somewhat similar plan was established a number of years ago by the proprietors of the locks and canals for the protection of the mill district in Lowell, Mass., and certain of the mills in Lawrence have connections from their individual fire pumps to a common main running the full length of the plants. While this plan has some disadvantages as compared with a system having supply and distribution under single management and control, it appears to be well suited to serve adjoining and common interests where the more expensive complete installation is not practicable.

A few years ago, when the question of installing a system in Boston was being discussed, the National Board prepared a pamphlet entitled "The Desirability of a High Pressure Fire System in the City of Boston." We had perhaps more difficulty in convincing ourselves that such a system was desirable in Boston than in most cities of its size, in spite of its narrow streets and congestion of buildings; because the city of Boston had already an unusually good system for supplying water to fire engines, besides having extensions from the domestic high service for serving automatic sprinkler equipments throughout most of the congested value sections. The arguments in that pamphlet may be summarized as follows, and will apply with equal or greater force in other large American cities: —

(1) The immense aggregations of buildings and contents in the business district of metropolitan cities, and the possibility of conflagrations involving tremendous losses and disastrous effect on business and civic growth, dictate the most effective known means of preventing such catastrophies.

(2) A large number of powerful streams can be concentrated on a fire in much shorter time and with fewer men and less apparatus than with fire engines.

(3) The protection of the rest of the city will not be weakened to the extent now necessary on third and fourth alarms from the district covered by the system.

(4) It will deliver its full capacity at any point in the district covered and at any desired pressure and can sustain this pressure as long as wanted.

(5) It eliminates the confusion entailed in the operation of a large number of fire engines, tends to prevent the misunderstanding of orders, and in every way simplifies operation.

(6) It provides protection to the congested value district even with a general alarm fire under headway in another part of the city, and forms an effective barrier against fires starting outside the district, while also affording the most efficient means of checking fires in the district which might otherwise involve a number of blocks.

Concerning the first of these items, I would not have you believe that there are no other effective and practicable means of offsetting the conflagration hazard. I recently had the pleasure of a discussion on this subject with the chairman of the London City Council Committee on Fire Brigades, which corresponds to the position of Fire Department Commissioner in American cities. He had been in New York about a week and was wondering why it was that, in spite of the vastly greater numerical and apparatus fire department strength as compared with London, we had such disastrous and destructive fires. When questioned, he stated what undoubtedly constitutes the answer to his problem, that in London the building ordinances prohibit any building more than 80 feet high, require fire walls to subdivide floor areas, and compel the protection of all openings in elevator shafts and other connections from floor to floor. These requirements, together with protection on exposed openings in exterior walls and with automatic sprinkler equipments in buildings of hazardous occupancy, would go very far towards making entirely unnecessary the powerful high pressure systems we are considering. However, the present situation and trend of development in American cities are such that structural conditions will for many years to come require the strongest possible fire protection facilities to offset them.

It is not an impossibility, even without a high pressure system, to concentrate numbers of powerful streams on a threatening fire in a large area building, as has been proved again and again in the city of Boston, where the water supply is ample and readily available and the fire department trained and accustomed to do that very thing. However, it is not a very common practice nor one readily accomplished without good training, as has been demonstrated in a number of cases recently, at fires which would have been much less destructive had these powerful streams been used. It is not so difficult to accomplish for the modern department equipped with automobile pumping engines as it was in the days of steam fire engines, which are much more awkward to handle and less able to maintain the pressure and discharge at which they are rated. However, even the automobile fire engine is at a disadvantage, since the largest of those in common use has a rated capacity of 1 000 gal. per minute at 120 lb. net pressure, and we may reasonably expect from each of the closer hydrants of a high pressure system an average of 2 000 gal. per minute at any pressure up to 250 lb. Also, such a system is much more flexible in operation as respects relocation of hose lines and regulation of pressures on individual lines than one which involves the use of fire engines.

Since July, 1908, when the high pressure fire system was put in service in Manhattan, the most extensive use made of it was in January, 1909, when it was brought into service for five simultaneous fires, three of them of more than usual severity, and one particularly so. At the extreme, seven pumps were being operated, delivering 33 500 gal. per minute against an average pressure of 225 lb. at the pumps and 205 lb. at the hydrants. Forty engine companies were called, including more than 600 men, and all the water thrown on the fire was from the high pressure system.

The system was also used on the occasion of the Equitable Building fire, and at a difficult fire in a general storage warehouse fire on Jane Street in July, 1922; because of a disastrous explosion in the early stages of this fire, it was not considered safe for firemen to remain in the building, and the fire was therefore drowned by streams from the outside; at one time sixty large streams, using a total of over 30 000 gal. per minute were in service, at a pressure of about 200 lb. at the hydrant, and a total of 87 000-000 gal. of water is reported to have been used. Each of these streams would require, if fire engines were used, the services of one fire company, whereas each company can lay and handle at least two or three lines from a high pressure hydrant to turret nozzles or water towers. It follows, therefore, that fewer companies will be required for fires calling for large quantities of water, and a much smaller part of the city will be stripped of its normal protection.

Conversely, in the event of a general alarm fire in another part of the city sufficient companies to man a reasonable number of streams will always be left in service for the protection of the district which is covered by the high pressure system; and should a fire originate outside the district and threaten the district itself, the concentration of streams which can be effected would constitute a means whereby such an exposure fire could be checked or narrowed with better success than in any other way, except perhaps by the interposition of sprinklered buildings, well provided with window protection; these latter are not frequent enough at present on the outer boundaries of most of our congested value districts to constitute a very reliable line of defence.

It is uncanny to witness the fighting of a large fire when only streams from a high pressure fire system are used. Instead of the noise and the apparent confusion when either steam fire engines or automobile pumping engines are used there is only the swishing noise of the streams as they emerge from the nozzles or strike the walls of the building. This, of course very much facilitates the issuing of orders by chief officers and simplifies operation in every way.

I shall not attempt to discuss definitely the question of reduction in fire insurance rates which has accompanied the completion of separate fire main systems in different cities. The National Board of Fire Underwriters has no jurisdiction and exercises no control in matters of this nature, and it is difficult to make a statement as to the amount of credit

which is in some cases a percentage of the base rate and in others a flat reduction; in any case, the matter is one to be decided upon by the insurance organization having local jurisdiction. In most cases, no credit is allowed in rates on buildings equipped with automatic sprinklers, in some cases none is allowed on stocks but only on buildings, and in others the principal credit relates to the item covering exposure hazard from other buildings.

Joint Discussion.

Mr. Booth. There is one point I overlooked at the time of writing my paper which is that a good many of the insurance companies, having doubt as to the adequacy of existing fire protection, will write greater lines on buildings after the completion of a high pressure system than they were willing to before. I think that was the case in the city of Boston. Some of the larger companies, which had limited their lines quite materially, felt that the city was enough safer after the system was installed to warrant their writing considerably larger lines.

I have not gone into detail on a great many things that occurred to me, thinking very likely there would be questions that would come up which would bring out those points. One that does occur to me right now as to operation is that in some cities, as you have noted from Mr. McInnes' paper, the system is used on all fires that occur within the area protected. In other cities it is used only on second or greater alarm fires. It is my opinion that the oftener it is used the more familiar the firemen become with its use, and the more likely they are to operate it effectively when the real severe test comes. For that reason we have always felt that it should be used on all alarms.

Mr. J. M. Diven.* What pressure is ordinarily maintained between alarms?

Mr. McInnes. About fifty-five pounds.

Mr. Diven. That would rather discourage a man who wanted to get it for some other use.

Mr. McInnes. Mr. Booth spoke of the uncanniness of operation of the high pressure system. That feature was strikingly exemplified to me at a fire in the sixth or seventh story of a building on lower Broadway about two years ago. The firemen ran several lines inside the building quietly, quickly and methodically; they also connected on the outside to fire pipes in the building. The smoke and flame which had been pouring out of the windows suddenly stopped. A visit to the pumping station showed that the delivery of water at first was 1 200 gal. per min. When the stage was properly set it jumped up to 7 000 gal. per min. and the fire gave out. The only excitement was afforded by a couple of thrilling rescues.

* Secretary of American Water Works Association.

Mr. Carleton E. Davis.* What is the limit beyond the fire hydrant that you can use this high pressure system?

Mr. McInnes. We figure 400 ft. under ordinary conditions. Undoubtedly effective work can be done 1 000 ft. away, using two or more lines siamezed.

Mr. Booth. There have been occasions where lines have reached 1 000 ft. in New York. In the Equitable Building fire, the pipe system was not extended to that point at the time of the fire, but it was close enough to enable effective use to be made of it. Of course you have to draw the line somewhere, and we have considered 400 ft. as a fair distance from the nearest hydrant, within which you would get reasonable normal protection.

Mr. William W. Brush.* As I recall, when we were working on the installation of the New York system, we estimated on 600 ft. as the extreme distance from a hydrant that we would consider the high pressure system to furnish effective protection. I want to ask Mr. McInnes whether he has any connection at all between his high pressure pipe system and his domestic lines, except from the pumping stations.

Mr. McInnes. None whatever, Mr. Brush, with the exception of the small by-pass through the station, to keep pressure on the high pressure fire system, with check valves, which we use to keep air out of the system, to be sure there is no air in the hydrants, and also use to measure the leakage. That is the only connection of any kind anywhere in the system.

Mr. Brush. There is no other connection to any private system which could be put in use by the Fire Department, except by stretching hose?

Mr. McInnes. None whatever.

Mr. Brush. In Brooklyn, we have two connections, between the high pressure and low pressure systems, so that the high pressure system can be used as an auxiliary service in case of a break down of one of the domestic pumping stations. Those connections have two valves on each connection and between the valves we have a drain pipe to take care of any seepage which may occur between the two systems.

If we ever have to put salt water in the system, and we doubt if we ever do, the possibility of any salt water getting in the domestic services through these connections is obviated by the drains at these connections. We have recently arranged to put in a connection that will be available for the Navy Yard in Brooklyn. That connection terminates in an open pipe, and the Navy Yard has to provide a large size special hose that can be used to connect the two systems. The naval authorities are required to notify both the Fire Department and the Water Department before they place the connecting hose. That is something that is very special, and we believe that connection is amply safeguarded in as much as there is no direct connection between the two systems, but this special hose connec-

* Chief, Bureau of Water, Philadelphia, Pa.

* Deputy Chief Engineer, Bureau of Water, New York.

tion can be connected up so that the Navy Yard in Brooklyn can have the high pressure water in case their own high pressure system fails.

Down at Coney Island, where there is the first high pressure system installed in New York, we had a number of connections to the amusement parks. These connections were put in at the request of the Fire Department, the proprietors of the amusement parks having urged the placing of such connections. After the Dreamland fire, if I recall correctly, the Fire Department then requested that these connections be closed and sealed because the Fire Department experienced trouble with the unauthorized use of some of the hydrants.

In Manhattan there have been cases where through error, intentional or otherwise, there have been small connections made from the high service into buildings, and the evidence tends to show the possibility of there being one or more such connections still existing on the system, but we have been unable to locate them. They, of course, do not represent any connection which would affect the delivery of the system.

We had rather an interesting experience with a couple of hydrants about which there is some difference of opinion as to the cause of the trouble. In April of 1918 the fire chief reported that at a fire the flow from one hydrant suddenly ceased. An examination was made of the hydrant immediately after the fire and there was nothing found to be the trouble with it. The hydrant was taken apart the following day and everything was apparently all right. At that time the only cause for the obstruction of flow through the hydrant that appealed to me was the possibility that ice had formed at a high point in the system, become dislodged, floated into the branch and cut off the flow. This spring we had a similar case as far as the cutting off of the flow was concerned. The pressure suddenly dropped from about one hundred fifty pounds to fifty pounds on one hydrant. We had been getting ample flow from the hydrant and several lines had been taken off this hydrant. The hydrant was examined within a few hours and then taken apart the following morning. Here again the hydrant was in perfect order when it was taken apart. The only explanation that I could personally give was that ice had floated in and temporarily closed the branch or hydrant valve opening. Those are the only two instances of that character, and the only instances that I can recall where there was any stoppage of flow through any one of the several thousand hydrants that we have on the system. Chief Kenyon did not agree with me on the ice theory in the first instance. In the second instance I do not recall that he made any comment.

President Barbour. What depth are the pipes laid? Are they all the same?

Mr. Brush. Four and one half feet. There are some places where they come up within two feet of the surface. I think 18 in. is the minimum depth we have from the surface to the main. Now, we have had one instance where the high pressure main was frozen solid, which was during

the severe winter of 1918. The pipe was cracked and had to be replaced. We have not had any instance where the general flow from the mains has been affected, as far as could be observed, by ice formation.

MR. DIVEN. Other hydrants in the neighborhood were working?

MR. BRUSH. Yes, there were several hydrants working on these two fires, and they worked perfectly, so that there was no trouble in the flow of water through the system. At the Jane Street fire one of the two pumping stations, during the height of the fire, experienced a break in a 10-in. check valve. The check valve suddenly seated and blew the casing top off, and the result was that the station was very thoroughly sprayed with water. The load was quickly transferred over onto the other station, and the Fire Department never knew anything about it. The station itself could probably have been kept operating on the fire if it had been essential to do it. Within an hour it was back again on the regular service. But this shows how a rather serious accident can occur in the pumping station and still keep the pressure up. There has never been a case where the stations have failed to function.

The Coney Island station, using gas engines, has not been as satisfactory as the electrically operated stations. We have had trouble there with engines and with pumps from time to time on large fires. I think that plant is in better shape to-day than it ever has been before. There have been changes made to make the pumps and the engines more reliable. But there we have had a lessening of the delivery of the station, so that the pressure has been low when the Fire Department desired service on one or two of the largest fires.

In the main system of Brooklyn, where we have two stations, we connected the Catskill system to the mains and put about one hundred pounds on the system two or three years ago, and since then have had less than a dozen runs a year with the two stations combined, so that in Brooklyn, where the Fire Department normally ask for 75 lb. at the start of the fire, the 100 lb. pressure takes care of all except about a dozen fires. The protected area runs several miles along the water front and a mile deep in the main district of the borough.

Also in Brooklyn the system was laid out so as to check the conflagration in the high pressure district rather than to eliminate the use of the steam or other power driven fire engines, and recently the Fire Department have asked us to extend the system so that they can do away with calling the fire engines in case of fire within the high pressure district. It would mean installing mains in intermediate streets that are perhaps six hundred or seven hundred feet apart.

We have one distinct difference in our system from the Boston system, and that is that we operate the plants, and in Boston the Fire Department operates the pumping plant. Also we get our messages entirely over the telephone; and, as I understood Mr. McInnes, they use the telegraph system and confirm over the telephone. We felt when the system was in-

stalled that the Water Department was more likely to have men suitably trained to look after the operation of the pumping station than the Fire Department, and while the Fire Department thought otherwise, there was not any very serious objection made to our department maintaining and operating, as well as constructing the high pressure stations, and I think to-day that the Fire Department in New York is perfectly satisfied with the system now followed. There never has been any friction, and the stations have always been able to give the water required, other than at Coney Island where the demand exceeded the station capacity.

Mr. McInnes. Mr. Brush, in the case of the hydrants that failed, did the flow entirely cease, or only diminish to such an extent as to be noticeable?

Mr. Brush. In the case of last spring, which I have clearly in mind, it dropped from 150 lb. to 50 lb. at the hydrant. In the case of 1918, while there was not a complete stoppage, there was a greater stoppage than occurred this spring. In both instances it was before April 10 that this difficulty occurred.

Mr. McInnes. Mr. Brush correctly stated that in Boston the Fire Department operates the stations, while the Public Works Department maintains the system. In Mr. Brush's case he has an excellent mechanical engineer equipment. We have nothing of the kind, and we are afraid of the combination. We are afraid of one fellow blaming the other, and we considered it would be safer and better to have everything in the hands of the Fire Department.

Now, in regard to the fire alarm. The Superintendent of the Fire Alarm fought hard and long, and succeeded in having it stipulated that all alarms should go first to headquarters and then to the station. His reason was, as I understand it, that particularly in the case of multiple fires there would be much greater danger of confusion and misunderstanding if orders were given by different men directly to the stations than if all orders came to headquarters, where a trained man would get them and would sift them out, sending only those that should be sent to the pumping station.

Mr. Brush. There have been one or two instances where the Fire Department men have failed to coördinate among themselves in telling the stations what to do. Whether they will change sometime and have the orders sent to headquarters and then transmitted or not, I do not know. Where we are operating on two or more fires we have cut down the pressure when ordered to do so when the fire chief at the second fire might prefer to have it kept up. There have been two or three instances, where the Fire Department operating on one fire sent a certain order, and from another fire a different order has been sent. In New York the men telephone directly from the box to the pumping station as to what is to be done.

Mr. McInnes. That was the outstanding reason in our case why it was thought that everything should go to the trained man who could best say what should go to the stations. Another reason, which I neglected

to mention, was that we in Boston have a dislike of telephoning, on the possibility of easily misunderstanding a number of different words, letters and sounds over the telephone, so that we were opposed to the use of the telephone for that purpose and very much preferred the telegraph with the telephone only for verification.

MR. BRUSH. I do not recall any instance where there has been any misunderstanding from the telephoning of orders. Confusion has only resulted due to orders being given by two separate fire chiefs operating on two separate fires at the same time.

MR. HARRY A. BURNHAM.* The National Fire Protection Association has a committee on private fire services from public mains and among the topics which they are about to consider, is the fullest use of these high pressure fire services. As fire-fighting equipment they are comparatively new in the history of fire fighting, and I think at this time we should approach the subject with considerable caution.

It seems to me this might be a good time to find out what the real reasons are for not providing connections to automatic sprinklers from these. I think that in some cases it perhaps can't be done. But in others— anticipating Mr. McInnes' reply — it seems to us a matter of control pure and simple, and if a proper and safe method of control could be worked out it seems as if one of the difficulties might be in a fair way to be solved in allowing sprinkler connections to be taken from these systems. It is a new subject, and I would like to know if that is the only objection to providing sprinkler connections from high pressure systems.

MR. DAVIS. In Philadelphia, where we have a comparatively low normal pressure, the underwriters, the sprinkler people and a number of builders urged very strongly that connections be made to the high pressure for sprinkler purposes. The Water Bureau opposed it strongly and will object until we see some reason that has not been presented at the present time.

In the first place, we do not know of any check valve that will be perfectly safe against interior pressure when there is a pressure possibly up to 250 lb. or 300 lb. Such a check valve as would prevent bursting of the sprinkler heads of the piping we do not know about, and do not want to be responsible for damage by water, neither do we want to have the high pressure diminished in case of a fire, at a very critical time, possibly, from that use. Furthermore, we do not believe that it is safe to put the high pressure fire system under the individual control of private buildings. We know that there is a very strong tendency, not only on the part of responsible people, but on the part of irresponsible employees, to make surreptitious connection inside. We do not know yet of any way to control that.

The high pressure fire system, as Mr. McInnes has said, should be the gatling gun, the last resort against a very serious conflagration. It is meant for that. The fire fighters have the right to expect that their high pressure

* Engineer and Special Inspector Factory, Mutual Fire Insurance Co.

system will be absolutely dependable. They are risking their lives, and if they have the high pressure fire system and are working it, they should be absolutely assured that it is perfectly safe. When you introduce pressure inside of the buildings you are going to have places, as Mr. Mc Innes said, where you will lose water. If any city goes to the expense of putting in a high pressure fire system it should be for high pressure service, external alone, and that only, from the Water Bureau or the fire-fighting point of view.

But I believe that there may be a tendency to over extend the high pressure fire service. If we were firemen we would want the high pressure fire service extended to the utmost. We would want to feel that we had this great flood of water which could drown out any fire, if it was necessary. But, on the other hand, if that tendency is met and the high pressure system is extended unduly, there may be, in certain cases, a tendency to diminish and not put so much stress on the extension of the ordinary water system, possibly not so much stress laid on increasing the ordinary water pressures, and that may tend to minimize the sprinkler service that would be obtained from the ordinary water pressure. At the present time we should give due weight to the fact that these large automobile pumping engines that Mr. Booth mentioned as available, are much more flexible, much more easy to control than the old time fire engine, and instead of extending the high pressure service unduly beyond certain definitely defined lines the money could be more profitably expended, in many cases, in larger mains, larger hydrants, and a larger number of modern, powerful fire engines.

In regard to the sprinkler people in Philadelphia. Mr. Diven suggested that we do not maintain high pressure all the time, but we do maintain ordinary city pressure, so that the mains are charged. But the thought was to put in one or two smaller units, to keep up the pressure at the station at a relatively small cost, and then in case of fire to put on the larger pumps.

There is another factor in Philadelphia, which does not hold in many cases, and that is that one-half of the system is charged with raw water from the Delaware River, and the other half is filtered water. Of course there is considerable objection to putting raw water in the buildings where connections might be made.

I might mention one other thing, and that is about the relations between the Water Bureau and the Fire Department. In Philadelphia the Water Bureau operates and maintains the high pressure fire system, including the operation of the fire hydrants at the time of the fire. At each high pressure station there is stationed one fireman on duty all the time, these being generally men who are crippled or hurt at the fires, and who are stationed there until such time as they recuperate, or perhaps permanently, depending on the nature of the injury. In fact, he is the liaison officer between the Fire Department and the Water Department.

Every fire alarm is recorded at the pressure station, and if it comes within the zone the pressure is raised to the minimum limit, I believe 75 lb.

or 100 lb. Then the Water Bureau sends a crew of men, uniformed but under the control of the Water Bureau, to the fire, and they operate the fire hydrants, and the firemen take the water from those hydrants just as they do from the ordinary fire plugs. There are telephone fire boxes scattered through the high pressure system, and orders through these district boxes are transmitted to the firemen at the high pressure station by the man who has charge of the fire, and the pressure is raised or lowered according as requests come in from the Fire Department.

Mr. Burnham. In reference to high pressure on the sprinkler system, it may be of interest to know that there are now several manufacturing plants where the sprinkler equipments have been under pressure of 175 lb. to 200 lb. for ten years or more. Of course that is an unusual condition. And no unfavorable experience has been met with those systems. As a matter of fact, the matter of mechanical strength can be taken care of if found necessary and advisable.

To raise the question again about the hydrant failures Mr. Brush mentioned, whether it was the practice in laying those high pressure pipes in Brooklyn to lay them as deep as the domestic service pipes? It occurred to me perhaps there being no circulation in those pipes, that they would be more apt to freeze.

Mr. Brush. It was the intention to put these pipes deep enough so as to avoid trouble of that kind, but where we had sub-surface conditions which could not be overcome in any other way than by raising the high service mains, the high service mains have been raised, and there has been provision made for opening a number of connections so as to create a circulation in those locations where it seemed likely from the local conditions that there might be freezing. But we have had no instance where the pipe froze solidly and broke except at Brooklyn at one station. We have had the two hydrants where the flow was suddenly cut off by an unknown cause. That, however, represents a record of about seventeen years.

Mr. Booth. I rather expected that this matter of automatic sprinkler connections would come up. We in the beginning approached the subject from the standpoint of the water works superintendent, because we are interested in municipal fire protection as a whole rather than in the protection of individual buildings. It is true that these systems were installed in practically all cases with the idea of giving the Fire Department the strongest weapon possible for use on outside fires. It is true also that in very few cases is the normal pressure carried sufficient to supply automatic sprinklers. San Francisco, if I remember rightly, is the only city that carried sufficient pressure. But I do think it is possible to so safeguard the connections as to make the automatic sprinkler practical and possible. I expect there will be come-backs on that.

I think Mr. McInnes, for instance, went too far in stating that the broken off connections at Salem, Chelsea and other places, were such a

serious handicap to the Fire Department. I think you should differentiate very strongly between the connection to an automatic sprinkler system and the connection for other purposes — for elevators, flushometer closets, and so on. The building with the sprinkler in it is so much safer, in the first place, than the ordinary building would be, that you are not running anything like the risk in putting your pipes in that building that you would if the pipe was for ordinary domestic or manufacturing purposes.

We have tried to find a record of as many cases as possible where connections to automatic sprinkler systems have been broken off and reduced the pressure unduly. There are very few of them. I wish you men would help all you can to get together cases of that kind. A great many references have been pretty indefinite. "A broken 6-in. connection in such-and-such a place in 1908 seriously reduced the water pressure." It is not very satisfactory when you get no more definite information than that. The Salem case, I will admit, was a marked one, where the automatic sprinkler supply failed to check the fire, the connections were broken off, and the system was bled very extensively. As a matter of fact, I do not know of any other such definite case where that happened, although there may have been other cases. In every conflagration that I know of there have been many broken connections of all sizes. Mr. McInnes, for instance, read the number and sizes of connections broken off in Baltimore during that conflagration. Although a great many of them were small they reduced the pressure very materially. In fact, that happens in any conflagration; your pressure will be reduced below the point at which you can use the Fire Department equipment with the normal degree of effectiveness. But even in cases like that of the Salem fire, there is in almost every case enough pressure left at the hydrant to give to the fire engine a fair amount of water — not as much as they could have used, but enough for one good stream from each engine. I think it is a subject that ought to be looked into further, particularly as to the differentiation between broken off connections to automatic sprinkler system and those for other purposes.

Mr. Davis suggested the point that if the way were opened to supply automatic sprinklers from these high pressure mains, they might become so numerous that it would be a very serious menace to the system. There is another angle to that, which is that I do not believe there is anything which would more greatly safeguard your city than a pretty general automatic sprinkler installation. Mr. Davis says it will very materially injure the system, but you have to look at it from the other point of view also, and if you get in enough sprinkler systems you will have a district without any great conflagration hazard.

Mr. Diven. Isn't it best to have a system independent of all these other conditions? Is there anything to fight the fire with when the other system gives out? Is it a distinct advantage to have an independent system?

Mr. Booth. I have not been able to satisfy myself that it is so much of an advantage as most of you think it is.

Mr. Davis. Where do the sprinklers do the most good; in the basements or in the higher stories? I understand the great majority of fires start in the basements. In most every system there is pressure enough to give a fairly satisfactory sprinkler service in the basement. Wouldn't that be a good starting point for the sprinklers?

Mr. Booth. That is entirely true. Of course any system will furnish a supply to a basement sprinkler. If you go that far you have gone a long way towards eliminating the fire hazard in the down town sections. The basement fires are most difficult to fight.

Mr. McInnes. I have to stand beside Mr. Davis with both feet. As an objector to connections from H.P.F. mains. But I want to be constructive as well. I can't clearly see how the ordinary high pressure fire system, in which there is effective pressure only at time of fire, can be effective with these little fires that start when the sprinkler must begin its work. Why cannot the same thing be obtained in a more effective way by providing means for such connection and making it the invariable and imperative practice of the Fire Department to make one of their first connections from the high pressure fire hydrant to the outside pipe, with check valve, supplying the sprinkler system? That has always seemed to me to be the sane way to get at it.

Mr. Booth. There is a whole lot in that, but not all Fire Departments are as progressive as the one Mr. McInnes knows about. It is only within a few years that a few of the larger and more progressive Fire Departments have been willing to make it absolutely standard practice to connect the first line, or the second line from the first company, to your outside sprinkler connection. They are coming to do it more and more frequently. And if they would do it consistently and in all cases, you would get the second connection made in time to serve as an adequate secondary supply. That is one solution of the problem which has been suggested, and it is good as far as it goes.

Mr. Brush. If I understood correctly, Mr. Booth suggested that the water works men get together on this matter of the connection with the high pressure system, with a view of working out some method whereby there might be additional connections allowed for sprinkler service. My suggestion would be that he keep the water works men as far apart as possible if he hopes to get that accomplished. Get them one by one and then sand-bag them. (Laughter.)

I know in New York an effort was made to have favorable consideration given to the question of making these connections. That was fought by the Water Department, and certainly until the Fire Department comes to the forefront on the proposition and says that it wishes to have these connections made, I am sure that no water works superintendent or engineer would take the responsibility of advocating connections which

are for the purpose of benefitting primarily the individual who owns the large building, or the building that requires the sprinkler system, whereas the high pressure system has been put in for the benefit of the community which includes a great many people who are not directly, and perhaps not indirectly interested in the fire protection of the one building. Of course we all appreciate that that one building may be the beginning of a fire which will cause a loss to the community, and if properly equipped with sprinklers that fire might never get headway in that building. But the individual can protect that building satisfactorily, and the community can, and usually does, furnish an adequate water supply outside of that building, which can be raised to sufficient pressure by the action of the owner of the building without endangering the continuity of the supply for the Fire Department from the high pressure system, which is distinctly a defensive system.

Mr. Burnham. I will add a statement about Salem. I think it was definitely established that there was a very large flow of water that drew the pressure down, but I do not think it was quite as definitely established that it was caused by the breaking off of the sprinkler connections. We looked into the matter quite at length and found that the locations of the sprinklered and non-sprinklered buildings at the start of the fire were such that the heat from the burning building which was not sprinklered, could open sprinklers in several stories in the sprinklered building. And we came to the conclusion that enough sprinklers could have opened in that way to have caused the drop of pressure attributed to the broken main.

Mr. McInnes. The main did not break. The buildings were burned, and there were pipes broken within the buildings. It was broken inside equipment which caused the trouble.

President Barbour. When I wrote Mr. Booth to ask him to contribute a paper, I suggested that it would be well to include in his paper a statement of the result of reductions in rates, which have followed the installation of these high pressure service systems. He has side-stepped this phase of the situation entirely and apparently the thought that rate reductions might reasonably follow the provision of what is proclaimed by the insurance men and the fire chiefs to be the greatest fire-fighting instrument yet devised has not forcibly registered on his mental screen. The divorcing of the engineering division of insurance companies from the income department is certainly a most convenient arrangement.

I may be a foolish optimist, but it seems to me that it should be possible to get on our record a statement of the economic return — if any — in reduction rates, which has accrued or may be reasonably expected to accrue to those cities which undertake large expenditures for high pressure fire service. So far as now appears there has been no such reduction in rates.

High pressure fire systems have as yet only been installed in large cities. I take it that a certain minimum total area of a certain value will justify high pressure service and I am wondering whether or not such areas

are found in some of our smaller cities. I have had the thought that the installation of high pressure service in such cities might naturally affect the design of the general distribution system, and that in some cases the reduction in the cost of this latter system might in part offset the cost of the high pressure service. I therefore hope that Mr. Booth will give us some idea of the value per acre in the districts of the various cities where high pressure systems have been deemed necessary.

Mr. Booth. That reminds me of one point I had in mind to discuss, which was the question of the type of city or district in which such a system might be warranted. Of course there is on the one hand a reduction of rates and a saving to the property owners. On the other hand, there is the possibility of saving to your city in the maintenance of its Fire Department. Your high pressure system can operate with fewer men, and perhaps with fewer companies. But your district must be of sufficient extent so that the companies located within that district won't have to cover any very considerable area outside of the district, otherwise you have to have the same number of men and the same equipment in pumping engines as you would without the high pressure.

Perhaps you will understand better what I mean if I say that in a district the size of this one in New Bedford, for instance, the down town companies on the first alarm, or at least on the second alarm, run from the mercantile or manufacturing section up into your residential district. Is that right, Captain?

Captain Gifford.* Yes.

Mr. Booth. Every down town company has a run outside of the district here?

Captain Gifford. In this town, yes.

Mr. Booth. So that your city must have a district of sufficient size to warrant the maintenance of companies in that district which have no or practically no runs outside. Otherwise, you have to have the same men and equipment as you would without a high pressure system.

I remember a few years ago the city of Hartford made quite an investigation to determine whether it was practicable to put in a high pressure system. They concluded that there would be little saving in Fire Department maintenance, on account of the fact that the district was comparatively small in Hartford. It would take about the same men and equipment.

Mr. Davis. Does the National Board recommend the lowering of rates?

Mr. Booth. We have nothing to do with that. We are supposed to keep our hands off. We do come in indirectly in this way: The National Board has a standard grading schedule which I think most of you know something about. It has been discussed in the meeting of your Association. In that schedule there is a provision for a removal of the points of

* Of the New Bedford Fire Department.

deficiency charged against bad construction conditions following the installation of the high pressure system. In Philadelphia, if I remember rightly, about half the points charged against bad structural conditions are removed because you have this powerful system. It is certain in that way to better the classification of your city.

Mr. Davis. Do you, after investigation, ever furnish the water works officials with the rating of their cities?

Mr. Booth. Yes, sir. On request.

Mr. Davis. Will you furnish it?

Mr. Booth. I will be glad to.

Mr. David A. Heffernan.* Hasn't the cost of maintenance of the Fire Department been increased greatly with the two platoon system? Have you any idea what the percentage of the increase is?

Mr. Booth. I suppose it has doubled up in a good many cases.

Mr. Heffernan. You said there was a saving to the cities with the high pressure system. With the two platoon system it would be the other way, wouldn't it?

Mr. Booth. I mean, it has decreased the cost of maintenance, because with the high pressure system you can run your department with fewer men and less expensive equipment. It is true that cities that have gone on the two platoon basis add on an average a third to the number of men. Your salaries have gone up, so that in a good many cases the total expense has doubled. We used to think that about two dollars or two dollars and one-half per capita meant a pretty good Fire Department, but now a good many of them run over four dollars, and some five or six dollars per capita.

Mr. Diven. One of the advantages, to my mind, of the high service system, is the possibility of a better sanitary supply for the city — a better general domestic supply. For instance, there might be a limited domestic supply, not sufficient for fire protection and the domestic supply, of an excellent quality of water which could be used if the same mains and the same system did not have to also supply the fire protection. This is, of course, meant particularly where the high service fire protection can be taken from an entirely different source. Most any water is good enough to put out fire; in fact, I have heard firemen say that the impure water was a little better than the filtered water for fires.

It seems to me that there might be many cases where that would be a very decided advantage to the city, and if the two systems could be designed together there would be a very great saving, perhaps, in the construction of the general or domestic supply system, as smaller mains could be used. You would not have to provide mains that would furnish a large quantity of water at a given part of the city at any time, when mains supplying much less than that quantity would answer all of the domestic purposes. A very decided advantage is the possibility in some cases of

* Superintendent Water Works, Milton, Mass.

securing a supply which is good in every respect, and an entirely separate supply for fire protection.

President Barbour. Mr. Booth, do you think it would be possible for us to get any statistics showing the average valuation of the districts that are protected by high pressure systems? If there are in some of the several departments of the insurance world, which are so carefully separated, such statistics in existence, and whether they are following the installation of these high pressure services by reducing the rates?

Mr. Booth. It would be pretty difficult, from what I know of the statistics available, to determine what the values involved in the districts are. I will try to get it.

President Barbour. I think that will be a very interesting basis for future consideration of the ordinary engineer who approaches this problem, if it can be gotten.

Mr. Booth. Jacksonville, Florida, is a good example of the smaller city that has been able to afford a system of this kind. That is largely because they operate a municipal lighting plant and get their power very cheaply. They were able to put up a pumping station on city owned land.

Mr. Diven. They use river water entirely, do they not?

Mr. Booth. Yes.

Mr. Diven. They are satisfied with very little.

Mr. Booth. In answer to your point made a little while ago, the total amount of water used on fires is a very small proportion of the total amount used for domestic purposes.

Mr. Diven. Yes; but it comes in big chunks.

Mr. Booth. Yes; but you almost always have mains large enough to supply the big chunks.

Mr. Diven. You would not necessarily have those if you had other mains to supply the fire protection.

Mr. Booth. In most cases they are already in. You have to have them until your high pressure system, if you put one in, protects the district in which your high pressure is necessary.

Mr. Diven. How about your filter plants? They would have to be larger if you used a filtered supply.

Mr. Booth. There are almost always areas outside of the system which demand about as much water as the mercantile district.

Mr. Diven. Not ordinarily. The high pressure ordinarily covers the congested district.

Mr. Booth. Yes; but there are almost always sections outside which demand about as much water. It has not ordinarily proved to be any material saving to the Water Department to attempt to use a second supply.

Mr. Lincoln Van Gilder.* Referring to the question of reduction of rates due to the high pressure system, I can't give you figures directly from memory, although I think they can be obtained from the Rating

* Superintendent Water Works, Atlantic City, N. J.

Bureau of the city. But I do know that Atlantic City recently got a 12 per cent. reduction in rates, due to better fire protection, or a better fire-fighting system; a better volume of water available for the city and also the high pressure. And this is in spite of the fact that the high pressure system has not yet been formally approved and that the rate was raised in every other city in the state. On the Board Walk, where the values are high, and where the class of buildings and the contents are very inflammable, the insurance rates in the past have been very high, but since the installation of the high pressure system the Rating Bureau has made a substantial reduction to those buildings on the Board Walk that are adjacent to the high pressure system, because of the high pressure supply, and before its formal approval.

There is another thing. The engine rooms are all supplied with an alarm, so that the alarm is struck through all the engine rooms at the same time it strikes on the general switch board in the Fire Department and Electrical Bureau, and they respond at once by giving 125 lb. pressure until further orders. The engine rooms are required to respond if the fire is within one block of the high pressure system.

On one occasion I recall a fire two blocks away on the Board Walk from the nearest plug — 850 ft. by actual measurement. The chief of the department made connection and got an effective fire-fighting stream.

PRESIDENT BARBOUR. There is another phase that has not been developed as fully as I think it might. Mr. McInnes has stated that only in one fire in Boston has more than 125 lb. at the pumps been called for.

MR. MCINNES. Ten per cent. of the fires.

PRESIDENT BARBOUR. I think that in Boston as yet, not more than 125 lb. has been called for.

MR. MCINNES. Not yet.

PRESIDENT BARBOUR. I am wondering whether there is any justification for the 300 lb. pressure, particularly in the smaller sized installations. I would like to ask Mr. Booth if he has an opinion to express on this question of pressure. It seems to me that the quantity of water at a certain minimum pressure is the controlling factor.

MR. BOOTH. That 300 lb. pressure I think was a figure that was assumed in the case of New York — not by the underwriters but by the city authorities themselves. I do not believe myself that there is any justification for such a high pressure. It has never been used in New York or anywhere else. I do not think we will ever have any more severe tryout of any of these systems than has already been had in two or more instances in New York.

PRESIDENT BARBOUR. Of course that must have a very direct influence on the cost of installation.

MR. BOOTH. Not so much so as you might think. Has it, Mr. McInnes?

Mr. McInnes. It is almost entirely in the thickness of the pipe. I agree with Mr. Booth entirely. So far as our city is concerned, 150 lb. is sufficient. But the increase in cost would not be so great as would appear at first thought. On the pumping station it would be very slight. There would be an increase in the strength of the walls of the pipe.

President Barbour. The increase in cost may not be so affected, but the risk is materially reduced by lighter pressure. Take the Boston situation. The regulators maintain a certain pressure beyond the pumps, but 300 lb. is always on the pumps in time of fire.

Mr. McInnes. That is right.

Mr. Booth. Of course you have to figure on some lines a good deal longer than others. In the case of a big fire, where you are using a good many hydrants, some lines will be 800 ft. or 1 000 ft. long. You have to figure on 90 lb. or 100 lb. at least at the nozzle. That means, with a line 800 ft. or 1 000 ft. long, with 3-in. hose, that you would have to have something more than 150 lb. at the hydrant. I think perhaps 200 lb. or 225 lb. is a fair maximum to expect that you might need.

Mr. Diven. Can you give us some data between the pump pressure and the pressure at the end? I think Mr. Brush may be able to give us something on that, because they have probably longer lines of fire pressure mains than any other city.

Mr. Booth. If I remember rightly, the New York system was designed to deliver 20 000 gal. per min. about any one block, with a loss in pressure not to exceed 40 lb. It will do better than that, I believe. What figures did you assume, Mr. McInnes?

Mr. McInnes. We assumed a loss of 50 lb., 12 000 gal. per min. in any block, pump pressure of 300 lb.

Mr. Davis. The pipe diameters which you gave — are they nominal or actual, inside or outside?

Mr. McInnes. They are actual pipe diameters.

Mr. Davis. You do not have the uniform outside diameter?

Mr. McInnes. No. Personally I question the wisdom of excessive thickness of pipe walls, as they have been made in many cases.

Mr. William R. Conard.* Regarding excessive thickness of pipe walls, in cast-iron pipe, which is the principal material used in high pressure fire systems; the strength of the metal is dependent on the inner and outer skin of the pipe, and the thicker the section of the pipe the more open and weaker the inner section; if you can grasp what I am trying to explain. To put it from the standpoint of metallurgy, as you increase your thickness the percentage of carbon in uncombined form in the inner section of the pipe wall, increases. That can be partially overcome by a change in your mixture, but there are in mixture changes, points beyond which you cannot go and expect to maintain your strength.

* Inspection Engineer, Burlington, N. J.

On the question of the pressures for the high pressure fire system it would appear to me that probably the 300 lb. was arrived at as a factor of safety, and the jump in thickness of walls from the class of pipe which would be used for maintaining a working pressure of, say, 125 lb. to 300 lb., is about 33 per cent., and that is reflected in the cost of the pipe in the system alone. The increase in proportions would not be so great in the other parts of the structure in a high pressure system, as I view it.

PRESIDENT BARBOUR. I note that Mr. Conard says that 300 lb. pressure is adopted as a factor of safety and, undoubtedly, a reasonable factor of safety is always necessary. But what about connecting sprinkler systems to these high pressure services? Surely this reduces the factor of safety in another direction, and if such connection is debatable, then the question of the necessary pressure is certainly relevant. It is a surprise to me to have Mr. Booth apparently favor this connection of sprinkler systems. My thought has been that an independent high pressure fire service is justifiable only as a means of external fire fighting, and because such a system provides a weapon free from all such disturbances as may result from any connection other than those under the control of the firemen.

MR. MCINNES. I think you are entirely right there. We consider it an extra insurance. When I look back at our calculations that is very clear to me. The pipe sizes used in Boston and New York are practically Class " H " H.P. Service A.W.W. While our figures call for lighter pipe, and it would be wise before large future installations are made to at least make an actual test to the breaking point of the lighter pipes before adopting the heavier type; apart from economy by reason of weight the lighter section makes more certain a uniform texture in the metal.

MR. DIVEN. To come back to the sprinkler system again. Sprinklers are supposed to put out fires with very small quantities of water, and certainly the domestic system will supply that much if they are connected with it. As I understand it, the high pressure systems between fires have only the ordinary domestic pressure, by a connection with the mains. Is that right? Between alarms you carry the same pressure on your high service that you do on the other?

MR. DAVIS. Yes.

MR. DIVEN. So that the sprinklers would be no more effective before the alarm was sounded and the pressure increased than they would be if connected with the domestic system, and as for the excessive use of your domestic system running the pressure down, it runs it down on the fire alarm just the same. I can see from that absolutely no advantage to the sprinkler system to be connected with the fire system, and a distinct disadvantage to the fire system by being connected and taking the risk of having a large waste of water by breaking the system by undue pressure in the sprinkler heads.

Mr. Frank E. Winsor.* Mr. Diven's last remark brought to my mind the fact that in Providence the condition that he has explained to you is not so. We have two systems of water supply there, two systems of pressure — a low pressure and a high pressure. The low pressure supplies water up to an elevation of about ninety ft. and the high pressure supplies that part of the city higher than 90 ft. In addition to that, the high pressure is connected into a high pressure fire district, generally in the low level part of the city, and those pipes, which it is true are connected into the same mains that supply domestic consumption in the high level district, have no connections in the low districts. In other words, buildings in the low service district which are too high to be supplied directly on the upper floors from the the low service, are not permitted to make any connection on the high service fire system for domestic use. Neither are there any sprinklers on the high pressure fire system.

Mr. Conard. That, as I understand the condition which Mr. Winsor has just described, is also true of the city of Newark, New Jersey, except that Newark has a gravity supply, and the high pressure system in the down town section gets its pressure from the high level system.

Perhaps Mr. Booth can tell us whether the sprinkler systems in the down town districts of Newark are connected with the high pressure system or the low pressure system.

Mr. Booth. They are all connected with the high pressure system.

Mr. Winsor. Perhaps I did not bring out that the low pressure system in Providence is also a gravity system, supplied by a reservoir. There is no pumping, other than to the distributing reservoir.

* Chief Engineer, Providence Water Supply Board.

ELECTRIC PUMPING AT CONCORD, N. H.

BY P. R. SANDERS.*

(September 15, 1922.)

The water supply of Concord, N. H. is obtained from Penacook Lake, which is two and one-half miles long and one-half mile wide, located about three miles from the center of the city.

The overflow is at an elevation of 125 ft. above the business section of the city. From 1872 when the system was installed until 1892, the total supply was furnished by gravity alone.

As the growth of the residential section extended westward into the higher parts of the city, it became apparent that steps must be taken to provide an increased pressure. In order to secure this increased pressure, in 1892 a high service system was installed consisting of a 2 000 000-gal. reservoir at an elevation of 200 ft. and a 2 000 000-gal. Worthington triple expansion pump.

In addition to using this high service supply for the higher section of the city, a 20-in. main was laid through Main Street for fire protection only, directly connected to this system, and this has later been extended to other business sections.

The pumping station is located between the city and the lake, on the main pipe line, about one mile from the center of the city and two miles from the lake and is supplied by gravity at static pressure of 50 lbs., from an 18-in. cement-lined main and a 20-in. cast-iron main which also furnish the gravity supply for the city.

In 1904 when the village of Penacook, a part of the city six miles north, was added to the high service, a second Worthington triple expansion pump was installed. Up to this time the daily average amount of water pumped was 400 000 gal.; after the addition of Penacook, it increased to 800 000 gal. The total daily consumption for all purposes is nearly 2 400 000 gal., 800 000 gal. from the high service and 1 600 000 gal. from the gravity service.

In 1917 when the United States entered the war and coal was needed for the manufacture of munitions and other war supplies, it seemed best after a thorough investigation of the matter, to release the quantity of coal used to run our plant and pump by electricity.

In this respect Concord is very favorably located, for power is manufactured by the Concord Electric Co., at their plant at Sewall's Falls, and the line is also tied in with the Manchester Traction Co. at Garvin's Falls, both of these plants being located on the Merrimack River.

---

* Superintendent of Water Works, Concord, N. H.

A rate was made by the Concord Electric Co. to the Water Works, by which they were to furnish us power at $1\frac{1}{3}$c. per K.W.H. After we had paid $1 800 there was to be no further charge until we had pumped 300 000 000 gal. and then the rate was to be $6 per million gallons pumped, figured on a yearly basis. All pumping was to be done at night between the hours of 8 P.M. and 6 A.M. except in times of fire or other emergency when we could pump as required.

A contract was made with the Worthington Pump and Machinery Corporation for an 8-in. single stage, horizontal, split case, double suction, volute pump, to have an efficiency of 72 per cent. when pumping 2 100 gal. per minute or 3 000 000 gal. per 24 hours, against a net operating head of 120 ft.

To drive this pump, we furnished an A.C. 100 H.P. General Electric motor of the squirrel cage type, to operate at a speed of 1,800 R.P.M., which was guaranteed by the makers to have an efficiency of 91.5 per cent. when operated at either full or three-quarters load. A 20 x 8 Venturi meter was placed on the discharge main. This pump was placed in service in August 1919.

As the water is taken directly from the mains that supply the city, provision had to be made to take care of the water hammer caused by the shutting down of the pump and a 4-in. relief valve was placed on the suction to discharge into the sewer set at an overload of 20 per cent. The pump operates against a check valve on the discharge side as it is not necessary to start against a closed gate.

No addition or new building was necessary as there was ample room in the existing engine room.

The steam pumps are kept for emergency and the fireman is released for other duties. A small heating apparatus was installed to heat the engine room, as it was considered too expensive to use the large steam boilers for that purpose.

A test of the pump was made for the month of September 1919, with a daily average of 654 333 gallons pumped, 340 K.W.H. used and a net head pumped against of 126.4, and the pump showed an efficiency of 85.18 per cent.

During the year 1920, the record of the electric pump by Venturi meter measurement was:

Water pumped, 308 879 000 gal.
Daily average pumped, 843 931 gal.
Gallons pumped per minute, 2 640 or 3 800 000 per 24 hours.
Total K.W.H. used, 156 610.
K.W.H. per 1 000 000 gal., 506.
Static head, suction, 50 lbs.
Static head, discharge, 88 lbs.
Dynamic head, suction, 37 lbs.
Dynamic head, discharge, 90 lbs.
Net head pumped against, 122 ft.

With switch board loss of 2 per cent. and motor efficiency of 91.5 per cent. this gives an efficiency of 84.25 per cent. The record for 1921 was equally good.

The cost of installation was as follows:

Centrifugal pump, foundations and fittings,	$2 415.22
Motor and switchboard,	1 291.50
Venturi meter,	1 406.16
Heating apparatus,	344.78
Total cost,	$5 457.66

The supplies used for the past year were 14 gal. of oil, 47 lb. of packing, 74 lb. of waste and approximately 12 tons of coal to heat the building.

The cost of pumping by steam figured on total pumping station expenses with no allowance for interest or depreciation charges was:

Year	Per Million Gal	Year	Per Million Gal.
1911	$11.65	1916	$15.40
1912	12.34	1917	16.22
*1913	19.49	1918	17.06
1914	13.12	†1919	15.14
1915	14.03		

*Excessive repairs. †Steam and electricity.

Cost by electricity,

1920	$13.16 per million gal.
1921	12.90 per million gal.

As wages and supplies were at least 33 per cent. higher in 1920–21 than in 1918, it is fair to assume that the cost per 1 000 000 gal. pumped in those two years would have been $22.70, pumping by steam.

The total pumpage for 1920 and 1921 was 578 737 000 gal. which, if figured on the above basis, would present a saving of $5 590 by the change to electric power; and in addition there is the advantage of the increased speed with which the pump can be started in case of fire.

DISCUSSION.

MR. J. M. DIVEN.* How much of those costs were labor?

MR. SANDERS. I should say one third.

MR. DIVEN. Of course you save in labor on the electric pump very largely.

MR. SANDERS. Yes. We save the cost of the fireman and handling of the fuel.

PRESIDENT BARBOUR. Did you consider automatic operation or did you keep the same number of engineers on the electric pumps?

MR. SANDERS. We kept the same engineer. No, we did not consider automatic operation at all. We did not feel it was safe to do it.

* Superintendent, American Water Works Association.

Mr. Diven. You were wise.

Mr. Sanders. And in addition to that, we pump at night, and the engineer has to ring up the police station hourly so as to make sure that nothing has happened and that the pump is not running without attendance.

Mr. Diven. It would seem to me that the peak of the load on the electric light plant would come in the night time, and that they would want you to take the day load.

Mr. Sanders. It does not in our town, because there are a great many granite manufacturers there, and their light load comes at night. Of course all that is required is to turn the Merrimac River through another generator.

President Barbour. Have you had any outages? Have you lost current? Did you have the ice storm that we had last November?

Mr. Sanders. No; the shut down has been practically nothing by electric troubles. We had a little motor trouble that caused a shut down.

Mr. Diven. Have you had any experience with automatic control?

Mr. Sanders. Never in water pumping.

Mr. Diven. I had experience in a small plant where they changed from steam to electricity intending to have it entirely automatic. A message came that this little suburban town was out of water. The power had been switched on about two miles from the pumping station. We found a pile of wreckage in the pumping station. The pump was absolutely to pieces.

Mr. Herbert C. Crowell.* Do you depend upon the electric pump entirely for pumping, or do you have some other power?

Mr. Sanders. We keep the original steam pumps there, in good operating condition, so that they are ready to start on short notice.

Mr. Crowell. What is the length of the transmission line?

Mr. Sanders. Three or four miles.

President Barbour. Have you a double transmission line?

Mr. Sanders. No; but the Sewall Falls, owned by the Concord Electric Company, is north of the city, and the Garvins Falls is south of the city, so that we can have it coming both ways. They are also tied in at Manchester with the plant there.

Mr. Crowell. Do you have to pay a fixed charge for the current? Do you have to guarantee to pump so much water?

Mr. Sanders. No, we do not. We pay $1\frac{1}{3}$ cents a kilowatt hour for all the power we use. That rate is figured on a basis of pumping 300 000 000 gal. of water a year. The maximum charge is $1 800. After paying $1 800 we do not pay any more until we pump 300 000 000 gal. of water, and after pumping 300 000 000 gal. the rate is $6 a million gal. It figures out approximately $6.40, but varies, of course, with the amount pumped.

Mr. Edmund Dunn. I am from Garfield, N. J. The first of January, we took over a steam-driven plant, with triple expansion Worthington

* Superintendent, Water Works, Haverhill, Mass.

pumps, similar to what they have in New Bedford, only horizontal instead of vertical. It was costing them $1.46 per thousand cu. ft. for pumping water out of deep wells. We installed an electric outfit and it is costing to-day 92 cents a thousand cu. ft.

Mr. Diven. How large a plant?

Mr. Dunn. About 2 000 gal.

Mr. Diven. How much are you saving on labor?

Mr. Dunn. Approximately $8 000 per year. We had three engineers and three firemen, paying 70 cents an hour to the engineers and 65 cents an hour to the firemen. We took them off. There are two men in the plant at the present time who are paid $100 a month. We have our Chief Engineer in case we have to start up an auxiliary steam plant.

Mr. Diven. How much are you pumping per day?

Mr. Dunn. We are pumping now 1 000 gal. a minute, running twenty four hours every day. We are getting the current at 1.17 cents per kw. hr. A guarantee is required to take 3 000 kw. hr. a month to get that rate but the use is unlimited.

Mr. Sanders. How is your power manufactured?

Mr. Dunn. It comes from the public service generated by steam power. The water is lifted out of the wells to a reservoir by an air lift system of about a half million gal. capacity. Pumps are the twin Valute type, made in Newark. I was quite surprised to hear Mr. Taylor say that the pump in New Bedford was only about 60 per cent. efficient. We get 70 per cent. efficiency. That is not a Valute pump in the strict sense of the word, but a centrifugal. A Valute pump is made on different lines and gives greater efficiency. We have one plant electrified, and later will electrify the other.

Mr. Diven. In the small plants the labor cost per million gal. is very high. I should like to hear from somebody who has a pump of ten, fifteen or twenty million gal. a day.

Mr. Dunn. I can tell you about paper manufacturers I am working with who have gas and steam power. They have the Corliss type of engine of about 3 000 h.p. But steam power to-day is no use without fuel oil or coal. We are installing public service through the whole mill. There is nothing to depend on whatsoever in that plant with the exception of one unit to keep our fire system in order, which we are compelled to maintain to meet the requirements of the fire insurance companies. We figure out a saving of about $30 000 a year by using the public service in labor alone. And then you haven't any coal to bother with. The coal question is not worrying you much over here, but we are sweating for coal at the present time. We expect to close some plants, and there are a number now closed for the want of coal. The Public Service Companies have the advantage of us because they get their coal direct from tide water, and don't have to bring it in by automobile truck or rail, as their plants are situated at tide water and they send the current over the Empire State with high pressure lines.

APPLICATION OF COPPER SULPHATE TO HARTFORD RESERVOIRS AND SOME EFFECTS UPON LENGTH OF FILTER RUNS.

BY J. E. GARRATT.*

For several years copper sulphate has been applied to the various reservoirs of the Hartford water system at certain seasons of the year when the numbers of micro-organism have become large. Previous to the filtration of the supply, which began late in the fall of 1921, the application of copper sulphate to the reservoirs was principally for the purpose of improving the taste and odor of the water. Since the introduction of filtration, the application of copper sulphate has continued for the purpose of lessening the amount of material which the filters have to remove from the water, and thereby lengthening filter runs and reducing costs of operation.

Copper sulphate is applied to the several relatively small old reservoirs of Hartford's supply by traveling over the reservoir surface in a small boat equipped with an out-board motor, with a bag of copper sulphate crystals suspended over the side of the boat and in the water. A course around the reservoir starting close to the shore and gradually working out to the center is pursued. The course is determined wholly by experience and judgment. If the desired amount of copper sulphate has not been dissolved by the time the center of the reservoir is reached, such a random course is continued as will spread the remaining copper sulphate through the whole reservoir.

With the new large Nepaug Reservoir recently added to Hartford's supply the application of copper sulphate is a much bigger proposition, as it is a question of dissolving two tons or so each time. Here an eighteen foot motor boat is available. By experiment it was found that, with two bags of copper sulphate held in the water, one from either side of the boat near the stern, the boat would travel at the rate of about 6 miles per hour and 50 lb. of coarse granular copper sulphate per bag, or 100 lb. from the two bags, would dissolve in 5 minutes, using coarse mesh grain bags.

With this information as a basis it is possible to lay out courses over any portion of the reservoir which it is desired to treat so that the required amount of chemical can be dissolved in a more or less uniform manner. This ordinarily gives courses about 100 ft. apart. The dissolved sulphate is considerably dispersed by the churning of the propeller of the boat, which is one of the decided advantages of a motorboat.

* Office Engineer, Board of Water Commissioners, City of Hartford.

The Nepaug Reservoir is formed by damming two streams. There are, therefore, two more or less distinct basins to the reservoir. The outlet from the reservoir to the pipe line to the filter plant is located in one of these basins, and an attempt is made to keep this portion of the reservoir low in micro-organisms.

This basin has a capacity of about 1 800 000 000 gal., is about 3 800 ft. long, and has an average width of about 1 800 ft. It was first treated on June 17, 1921, when total micro-organisms at the surface numbered 1 300 (principally *Asterionella* 750 and *Cyclotella* 500) and at a depth of 30 ft. numbered 350 (*Asterionella* 200 and *Cyclotella* 100). It was decided to treat at the rate of 1.5 lb. per million gal., which required 2 700 lbs. of copper sulphate for the 1 800 000 000 gal. in the basin. To dissolve these 2 700 lb., using two bags from the motor boat, required 27 x 5 minutes, or 2 hours and 15 minutes. During this time at a speed of 6 miles per hour the boat would travel about $13\frac{1}{3}$ miles or about 72 000 ft. The average width of the basin being 1 800 ft. it is seen that 40 trips across would be required; and since the length of the basin is about 4 000 ft. the courses would be 100 ft. apart. These courses were laid out on a plan, and land marks only were used as guides when the courses were traversed. The motor-boat carried twelve 50 lbs. bags of sulphate besides a crew of three men, one to guide the boat and two to dissolve the copper sulphate. Since the rate at which the sulphate dissolved was much more rapid when the 50 lb. bag was first immersed, a more uniform rate of dissolution was obtained by putting a new full bag overboard on one side of the boat at the time that the bag already overboard on the other side was about one-half dissolved. No attempt was made by the men handling the copper sulphate to dissolve the last handful or two. When this stage was reached he passed the bag forward to the man steering the boat, who dissolved the small remaining amount while the main operation continued. It took a little over three hours to apply the 2 700 lb., two hours and fifteen minutes of which was actual time on the course and the remainder was time used in returning for other boat loads of sulphate.

Water samples taken at two widely separated points on June 21, four days after treatment, showed that the total number of micro-organisms at the surface had been reduced to about 300 (*Asterionella* 150 and *Cyclotella* 130). Some few small fish were killed by the treatment. About six pailfuls were picked up along the shore.

At this same time several smaller coves and portions of the reservoir, so located as to be conspicuous from the highway, were treated with equally successful results. The previous year a green algae scum formed in certain of these coves. None occurred during 1921 after the copper sulphate was applied. The micro-organisms remained low in number throughout the remainder of the year.

The new filtration plant was started in a small way during November, 1921. Only part of the total supply was filtered. Permanent rate of flow

and loss of head gages were not yet installed and only a temporary sand washing outfit was available. Piping is so arranged that water can be taken either from the Nepaug Reservoir, from the old West Hartford reservoirs, or from both sources at the same time. The water to the filters was taken first from the big Nepaug Reservoir. The number of filter units in use was gradually increased until early in February, 1922, the whole supply to the city was being filtered. Nepaug water was used until the middle of March. During all of this time the micro-organisms, which were very low in number, totaled about 50 (maximum 80 and minimum 25). The average amount of water passed between scrapings or rakings was about 125 000 000 gal. per $\frac{1}{2}$-acre bed.

From March 17 to April 3, while high colored bottom water was wasted from the Nepaug Reservoir previous to the spring turn-over, water to the filters was taken from the West Hartford reservoirs. This raw water had a color of about 25. The numbers of micro-organisms were not as low as in the Nepaug water but they were relatively low; 80 on March 17 and increasing to 185 by April 3. A filtered water with color of about 15 was obtained, and the rate of clogging during this short period indicated that the quantity of water filtered between cleanings or rakings would have averaged about 100 000 000 gal. per $\frac{1}{2}$-acre bed, had water of this character continued through the filters.

Nepaug water was again put onto the filter beginning April 3. By the end of the month micro-organisms had increased to 150 or so, more than one-half being *Asterionella*. In anticipation of the probable need of treating the Nepaug Reservoir with copper sulphate as was done the previous year, the principal West Hartford reservoirs in which the total micro-organisms had gradually increased to from 240 to 300 (in two *Asterionella* was the principal micro-organism and in another *Nitzschia*) were treated with copper sulphate at the rate of 2.3 lb. per million gallons early in the month of May in order to have them available with water low in micro-organisms for use while the big reservoir was being treated.

Early in May, with Nepaug water, filters clogged very rapidly. Runs of as little as 40 - 45 million gallons per $\frac{1}{2}$-acre bed were the rule. It began to look as if night shifts would be needed on the washing outfit. On May 22 Nepaug water was shut off so that the reservoir could be copper sulphated. While the total number of micro-organisms did not seem large, yet there were several times as many as in the water which had been used previously. At the surface they totaled 300 and at the depth of 30 ft., 200. It was decided to treat the portion of the Nepaug Reservoir near the intake, that is, the same portion as was treated the previous year. Twenty-four hundred (2 400) pounds of copper sulphate were applied on May 23 in the same manner as during the previous year except that fine mesh burlap bags were used so that no fine grains of sulphate could escape. This was at the rate of about 1 3 lb. per million gallons of water treated, as compared with 1.5 lb. per million gallons the previous year. The predominating micro-organisms

were *Uroglena* 50 per cent. and *Asterionella* 30 per cent. The treatment, however, was without material results. Total organisms at the surface were not reduced in number while at the depth of 30 ft. they increased very materially to about 600 total.

In the meantime, the treated West Hartford reservoir water with total micro-organisms of 50 to 100 was put onto the filters, filter runs lengthened appreciably to 65 or 75 000 000 gal. between washings, and the washing emergency was passed.

But it was desired to use Nepaug water as soon as possible so it was decided to treat the same portion of this reservoir again and at a rate of about 2.5 lb. per million gallons. On June 3, 1922, four thousand (4 000) pounds of copper sulphate, all of which was on hand at that time, were applied. This was at the rate of 2.3 lb. per million gallons. Total micro-organisms were 250 at the surface and 600 at a depth of 30 ft., half *Asterionella* and half *Uroglena*. Quite a few small fish were killed. Samples taken three days after treatment showed slight reduction in *Asterionella* and practically no reduction in the number of *Uroglena*. Samples taken the following day, June 8, showed still further reduction in the micro-organisms at the surface (average total 140), but large increase in number at a depth of 30 ft. (average total 1 030).

On June 9 the change back to the Nepaug water was made, taking water from the intake nearest the surface where the micro-organisms were the lowest in number. On June 14 conditions were the same as on June 8, but by June 21 surface counts had decreased to an average of 65 and at the 30 ft. depth to an average of 100.

As a result of more or less off hand consideration of all this, it appeared that all that was necessary to do in order to keep filter runs long was to keep micro-organisms low in number. Careful watch, therefore, was kept of micro-organisms. No considerable increase was noticed in the Nepaug water, but all of a sudden, early in July, filter runs of 18, 20, 21, 23, 25 million gallons were gotten. Experience had shown that filters could be lightly raked over once or even twice without materially increasing the amount of sand to be scraped off and washed ultimately, so that no washing crisis seemed at hand, but on several beds there were periods of only ten (10) days between rakings or scrapings and in one case only seven (7) days.

While water in the Nepaug reservoir was low in micro-organisms it was found that water in the West Hartford reservoirs, into which the pipe line from Nepaug emptied, had developed a considerable growth of micro-organisms (*Nitzschia*), so on June 8 this reservoir (Reservoir No. 5 so-called) was shut off and the Nepaug water allowed to pass directly to the filters. Reservoir No. 5 normally is used like a surge tank to take care of the excess or to supply the deficit of Nepaug water, over or under the amount passing through the filter at any time.

About July 11 Reservoir No. 5 was treated with 2.3 lb. of copper sulphate, per million gallons the micro-organisms reduced from 270 to about 100 by July 18 and on that day the gate on the line to and from the treated Reservoir No. 5 was opened again. At the time this treated water was again free to pass onto the filters, one ½-acre bed had only passed 30 000 000 gal. of water and had lost three (3) of its five (5) ft. of head. Other beds had either just started on new runs or were practically at the end of runs of 20 to 25 million gallons as stated above.

A few days later it was noticed that loss of head on the bed which was in the midst of a run, Bed 3 so-called, began to decrease. It continued to decrease. At the same time a slimy deposit on the walls and bottom of the walls and bottom of the aerator disappeared. Bed 3 gained a new lease of life and continued in service until August 24, passing 90 000 000 gal. of water. Runs on other filters since the last of July have varied from 45 to 80. Micro-organisms in Nepaug reservoir have continued low, 30 to 50. But at the present time, August 25, micro-organisms in Reservoir No. 5 have again increased to over 300 without as yet causing any noticeable increase in the rate of clogging of the filters.

Presumedly we have not as yet gotten the whole story in regard to the amount of copper sulphate needed for effective treatment or in regard to the relation between number of micro-organisms and lengths of filter runs; but it is thought from the information so far collected that the application of copper sulphate has possibilities as an aid to economical filter operation with Hartford's water.

Discussion.

Mr. Garrett. In the matter of the application of copper sulphate to the reservoir, we have always been very careful not to put so much in as to kill the fish.

Mr. J. M. Diven.* On the matter of killing fish my observation has been that the game fish are seldom killed, — but it is such fish as carp, for instance. At the Troy Reservoir we took out six tons of carp. They are a mud fish, and work around in the bottom. The water being a little turbid, the copper sulphate was carried to the bottom and the fish got it. In all that six tons I think there was only one black bass that was killed.

---

* Secretary American Water Works Association.

WATER SUPPLY OF SOUTHEASTERN MASSACHUSETTS.

BY X. H. GOODNOUGH.*

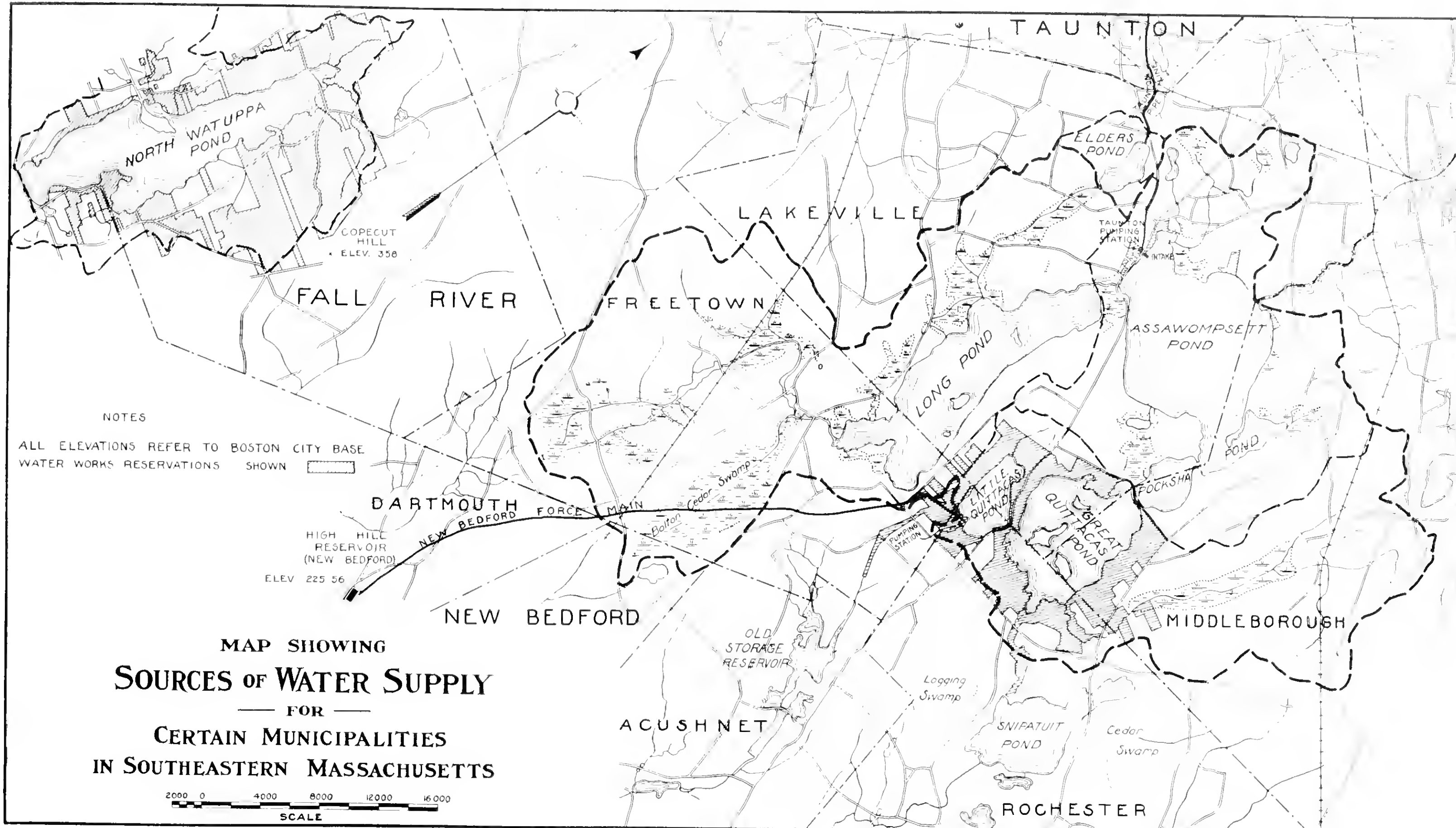
[*September–1922.*]

Southeastern Massachusetts is a term ordinarily used to designate that part of the Commonwealth included in the old Plymouth Colony which at present comprises the counties of Plymouth, Bristol and Barnstable on the mainland and the island counties of Dukes and Nantucket. In the counties of Barnstable, Dukes and Nantucket there are no large centers of population and local water supplies are readily available which from present prospects are ample for all probable needs. Plymouth County contains but one large city, Brockton, amply supplied with water from sources situated in a region in which supplementary water supplies are readily available to meet future requirements. Plymouth, the next largest municipality in this county, has also an excellent water supply in a region of abundant further resources.

The greatest concentration of population in southeastern Massachusetts is found in the county of Bristol and is centered chiefly in the three principal cities — Fall River, New Bedford and Taunton. These cities contain many of the most important textile industrial plants in New England if not in the whole United States.

It will be shown later that Fall River and New Bedford, which together contain nearly 87 per cent. of the population of the three principal cities of southeastern Massachusetts under consideration, exclusive of the adjacent towns, are already using nearly all the water that their present sources of supply can safely be relied upon to furnish. If these cities continue to grow and to use more and more water, as has been the case in the past, additional water supplies must be secured, immediately in the case of Fall River, and within a very few years in the case of New Bedford, or a shortage of water supply will be experienced in the next dry period. Estimates of the population and of the quantity of water likely to be required for the supply of these cities which will be presented indicate that their population may be expected to double within the next fifty to sixty years if their growth continues approximately as shown by past experience. (See Diagram No. 1.) These estimates may seem large, but even if these cities should grow more slowly the quantities of water required for their use will equal the estimates within a comparatively few years beyond the time indicated. Fifty years is a short period in the life of a city, and many of the present inhabitants of these cities in the natural course of events will still be dwelling there at the end of that period.

*Director and Chief Engineer, Mass. Dept. of Public Health.


TAUNTON
NORTH WATUPPA POND
COPECUT HILL
ELEV. 358
FALL RIVER
FREETOWN
LAKEVILLE
ELDERS POND
TAUNTON PUMPING STATION
INTAKE
ASSAWOMPSETT POND
LONG POND
POCKSHA POND
LITTLE QUITTACAS POND
GREAT QUITTACAS POND
PUMPING STATION
MIDDLEBOROUGH
NOTES
ALL ELEVATIONS REFER TO BOSTON CITY BASE
WATER WORKS RESERVATIONS SHOWN
DARTMOUTH
NEW BEDFORD FORCE MAIN
Bolton Cedar Swamp
HIGH HILL RESERVOIR (NEW BEDFORD)
ELEV 225 56
NEW BEDFORD
OLD STORAGE RESERVOIR
Logging Swamp
SNIPATUIT POND
Cedar Swamp
ACUSHNET
ROCHESTER
MAP SHOWING
SOURCES OF WATER SUPPLY
FOR
CERTAIN MUNICIPALITIES
IN SOUTHEASTERN MASSACHUSETTS
2000 0 4000 8000 12000 16000
SCALE

The industries of these cities have long been established and there is no reason why their growth should cease or even be materially restricted, in the immediate future at least, on account of the establishment of similar

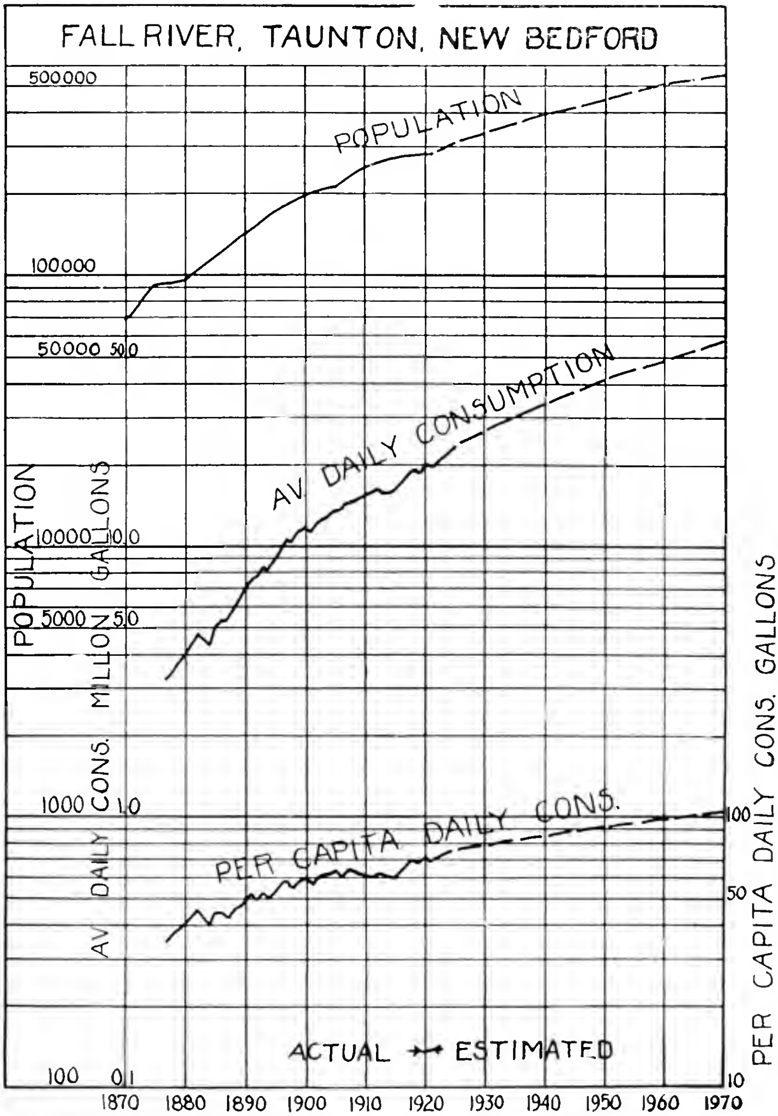


DIAGRAM No. 1.

industries elsewhere or from any other cause that is apparent at the present time. The great manufacturing cities of England have not declined because of the growth of similar industries in England or in any of the other countries. On the contrary, those cities have grown steadily, and

for more than half a century their growth has been as rapid or even more rapid than is here estimated for the cities of southeastern Massachusetts, though the English cities have attained a much larger size. (See Diagram No. 2.)

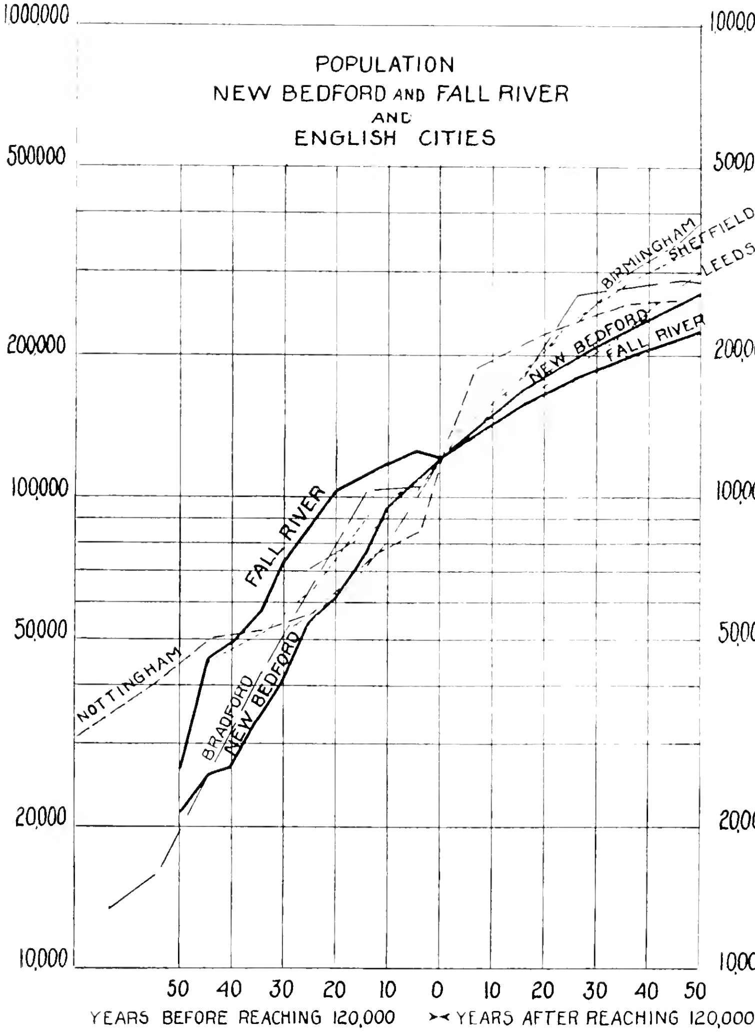


DIAGRAM No. 2.

Except for the natural ponds, the region of southeastern Massachusetts is a singularly unfavorable one in which to obtain large quantities of unpolluted water for domestic uses within reasonable limits of cost. The valleys in general are wide and flat and are occupied commonly by extensive swamps. In consequence, the waters of the streams are usually highly colored and contain large quantities of organic matter. The rivers and water courses in many cases are exposed to pollution from towns and

villages on their watersheds and from manufactories producing large quantities of objectionable wastes which find their way into the streams. The contours of the valleys, as a rule, are poorly adapted for the construction of reservoirs of large size unless by the flooding of swamps which would produce waters of highly objectionable quality. Two remarkable groups of natural ponds, however, characterize the topography of this region, and they include the largest natural reservoirs in the State. One group, known as the Watuppa Ponds, lies adjacent to and partly within the city of Fall River and from the northerly pond of this group, known as North Watuppa Pond, the city of Fall River has obtained its water supply since water works were first introduced into the city in 1874. The other group, known as the Lakeville or Middleborough Ponds, is situated partly in Lakeville and partly in Middleborough with small portions in Freetown and Rochester, and has been used as the source of water supply for the cities of New Bedford and Taunton for many years, the former taking its supply from Little Quittacas Pond supplemented by Great Quittacas Pond, while Taunton supplies itself from Elder's Pond supplemented with water pumped into Elder's from Assawompsett Pond.

The Water Supply of Fall River.

The Watuppa Ponds have thus far furnished all of the water used in Fall River for water power and for domestic and manufacturing uses, — the domestic water supply, including all water supplied from the municipal works, coming from the North Pond.

These ponds have been carefully surveyed and mapped and accurate information is thus available as to their storage capacity and the areas of their watersheds.

From this information the following table is presented showing the original drainage area of each pond and the area and capacity of the North and South Watuppa Ponds respectively, together with the changes due to diversions from the watershed of North Watuppa Pond designed for the purpose of preventing pollution of the water to which reference will later be made.

Drainage Areas and Area and Capacity of Watuppa Ponds.

Pond.	Original Drainage Area (Sq. Mi.).	Drainage Areas after Completion of Diversion Works. (Sq. Mi.).	Area (Sq. Mi.)	Approximate Capacity (Mil. Gals.).
North Watuppa Pond	11.41	8.51	2.82	7 200
South Watuppa Pond	16.10	19.00	2.12	8 000

With the available records of rainfall for this region, which cover in some cases very long periods of years, and with the measurements of the flow of North Watuppa Pond which were maintained for a number of years by the city of Fall River, sufficient data are available for computing within narrow limits the probable safe yield of these ponds.

With this information estimates of the safe yield of North Watuppa Pond indicate that about 7 million gal. per day can be drawn from the pond without lowering the water level more than about five feet. It is possible by drawing the pond to a lower level, and thus utilizing a greater portion of the storage, to enlarge somewhat the yield of this source, but a draft of more than about 8 million gal. per day would be likely to exhaust the storage in the pond in a dry period. It is desirable to retain as large an amount of water in the pond as practicable for several reasons, especially for the purification of the water and the protection from the effect of possible pollution which storage affords, and the limit of 5 ft. in the draft from this pond is a reasonable one under the existing circumstances.

The quantity of water used in the city of Fall River since 1890, the population of the city, the consumption of water per capita, number of services and per cent. of services metered, are shown in the following table:

Year.	Population.*	Average Daily Consumption (Gallons).	Per Capita Daily Consumption (Gallons).	No. of Services.	Per Cent. of Services Metered.
1890	74 398	2 136 000	29	4 980	75
1891	77 359	2 356 000	30	5 247	76
1892	80 320	2 286 000	29	5 526	77
1893	83 281	2 334 000	28	5 793	78
1894	86 242	2 438 000	28	6 138	80
1895	89 203	3 167 000	35	6 372	82
1896	92 335	3 547 000	38	6 704	84
1897	95 467	3 670 000	39	6 422	93
1898	98 599	3 136 000	32	6 576	93
1899	101 731	3 581 000	35	6 783	94
1900	104 863	3 805 000	36	6 943	94
1901	105 043	3 619 000	34	7 075	96
1902	105 223	4 365 000	41	7 282	96
1903	105 402	4 278 000	41	7 502	96
1904	105 582	4 092 000	39	7 667	96
1905	105 762	4 407 000	42	7 744	97
1906	108 469	4 478 000	41	7 845	98
1907	111 175	4 941 000	44	7 956	98
1908	113 882	4 968 000	44	8 108	98
1909	116 588	5 340 000	46	8 316	99
1910	119 295	5 200 000	44	8 501	99
1911	120 394	5 177 000	43	8 790	99
1912	121 493	5 335 000	44	8 988	100
1913	122 593	5 636 000	46	9 289	100
1914	123 692	5 967 000	48	9 497	100
1915	124 791	6 086 000	49	9 793	100
1916	123 930	6 068 000	49	10 069	100
1917	123 069	6 346 000	52	10 210	100
1918	122 207	6 344 000	52	10 290	100
1919	121 346	5 907 000	49	10 382	100
1920	120 485	6 376 000	53	10 500	100
1921	120 485	6 971 000	58	10 671	100

* Populations for other than census years are estimated.

From the above table it appears that the quantity of water used in 1921 is practically equal to the safe yield of this source of supply. It will be noted that the per capita daily water consumption in the city of Fall River has in the past been less than in almost any other large manufacturing city in the State. This condition has been due to several causes, prominent among which is the fact that the South Pond and the Quequechan River furnish an ample supply of excellent water for manufacturing uses, and as the principal industries of the city are situated for the most part along this pond and river a large part of the water used for manufacturing and mechanical purposes is taken from those sources, thus relieving the draft from the municipal works. Furthermore, as the table indicates, meters have long been used very generally in Fall River and for many years practically all of the water used in the city has been supplied through meters. While the consumption per capita was much smaller than in any other city for many years after water works were introduced, it has been constantly increasing notwithstanding the use of meters, and there is no reason to doubt that with improving standards of living and with the introduction of new industries there is likely to be a still further increase in the consumption per capita which must be taken into account in planning for future extensions of the water supply system.

The selection of a source of additional supply involves the problem of the allowance to be made for the growth of population and increase in the use of water in order to furnish a reasonable basis for comparison of the relative advantages of available sources. The growth of Fall River, like that of the other textile cities in the State, has been uneven, having been very rapid in some periods and slower in others according to the varying prosperity of such manufacturing centers, most of which, though on the whole growing steadily larger, have shown a decline in population at times. The city of Lowell, for example, decreased slightly in population between 1855 and 1860 due to poor business conditions, and a marked decrease amounting to 5 837 in number occurred during the period between 1860 and 1865 due to conditions brought about by the Civil War. The city of Lawrence declined in population slightly between 1880 and 1885 though it has since increased rapidly with the establishment of the woolen industry in that city. The city of New Bedford, in common with many other places, declined in population during the period of the Civil War, from 1860 to 1865, but with the establishment of the textile industry that city has grown rapidly in recent years.

The city of Fall River grew very slowly in the period 1900 to 1910 due to unfavorable industrial conditions, and during the period of the great war, from 1915 to 1920, the population actually declined nearly 4 per cent. But it is unreasonable to conclude from the decline in the population of Fall River during the war that that city will continue to decline in population or even that it has reached the limit of its growth.

In view of the experience of other industrial cities, the only safe course in selecting an additional water supply is to assume that the population will continue to grow, more or less irregularly probably, as has been the case in the past, but on the whole continuously for a considerable time in

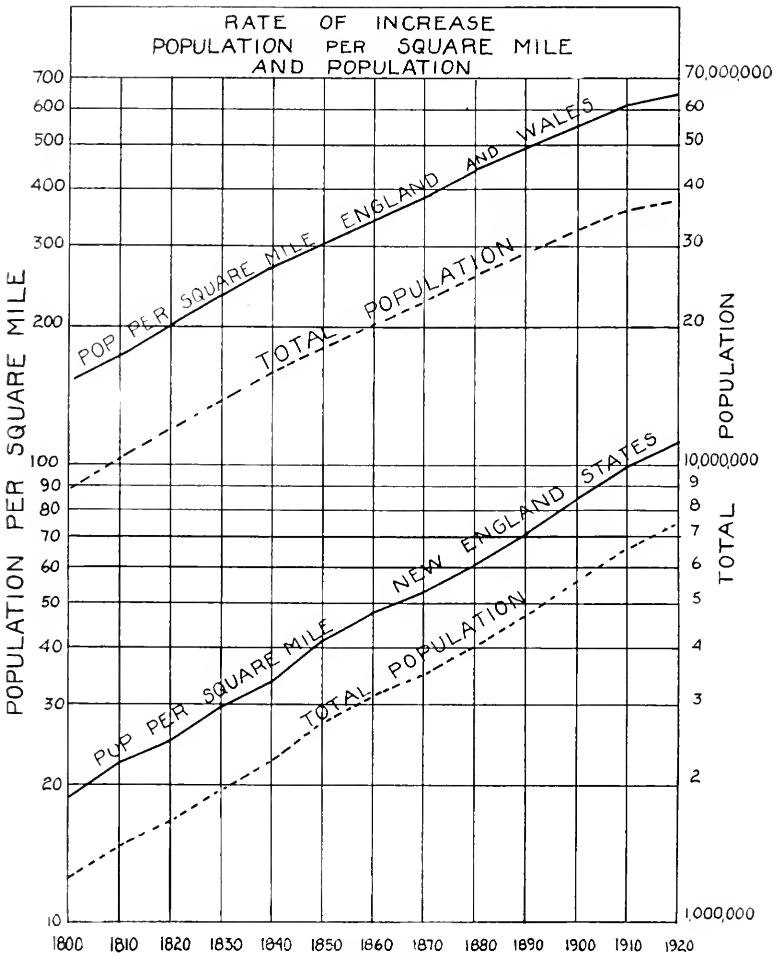


Diagram No. 3.

the future. In view of the growth of English manufacturing cities situated in a far more densely populated country than the United States or even New England to-day, it is unreasonable to assume that large manufacturing cities have reached the limit of their growth.

In diagram No. 2, the growth in population of several of the large industrial cities in England * was shown as compared with Fall River and

*Some of these cities have recently grown more slowly than formerly. Whether these conditions are due to a restricted area or to consequent overflow into adjacent districts has not been ascertained.

New Bedford both before and after the English cities had attained a population of about 120 000, which was the population of both Fall River and New Bedford in 1920. Diagram No. 3 shows the rate of growth of England and Wales and of the New England States.

Assuming that the city of Fall River will continue to grow about as it has in the past and allowing for a gradual increase in the consumption of water per capita, the quantity of water required for the supply of the city has been estimated as follows: (See also Diagram No. 4).

Year.	Population.	Per Capita Daily Consumption (Gallons).	Average Daily Consumption (Gallons).
1920*	120 485	52.9	6 371 000
1925	132 800	56.9	7 556 000
1930	144 500	60.6	8 757 000
1935	155 800	64.1	9 987 000
1940	166 800	67.4	11 242 000
1945	177 200	70.5	12 493 000
1950	187 500	73.4	13 763 000
1955	197 200	76.1	15 007 000
1960	206 800	78.6	16 254 000
1965	215 800	80.9	17 458 000
1970	224 800	83.0	18 658 000

While these estimates may seem unreasonably large it does not appear to be safe to take smaller figures in view of the circumstances which are likely to favor the further growth of this city, and in view also of the possible extension of its water supply system into adjacent territory.

The Quality of the Water of the Watuppa Ponds.

The water of the North Watuppa Pond is naturally soft, low in color and of excellent quality for domestic use. Many years ago, owing to the increase of population within the watershed of the pond, the city began the purchase of lands within the watershed and now owns nearly 60 per cent. of the area at present tributary to North Pond. In parts of this watershed on the westerly side of the pond in the drainage areas of Cress, Highland and Terry Brooks the population had increased to such an extent when the threat to the water supply was realized that it was found impracticable to purchase the lands except at a cost which was prohibitive, and in certain other small areas at the easterly side of the pond in the watershed of Nat and Ralph Brooks the increase in population had become such as to make the cost of protection by acquiring these areas excessive. The plan was then adopted of diverting the flow of water from objectionably populated drainage areas by means of intercepting drains, and a large intercepting drain was completed on the westerly shore of the pond in 1916 by which all of the flow from the populated areas in that part of the watershed is diverted into the South Pond. Plans were prepared at that

*Figures for 1920 actual, all others estimated.

time for diverting into the South Pond the flow of a large part of the drainage areas of Nat and Ralph Brooks on the easterly side of the pond, but the construction of the necessary works was interrupted by the war.

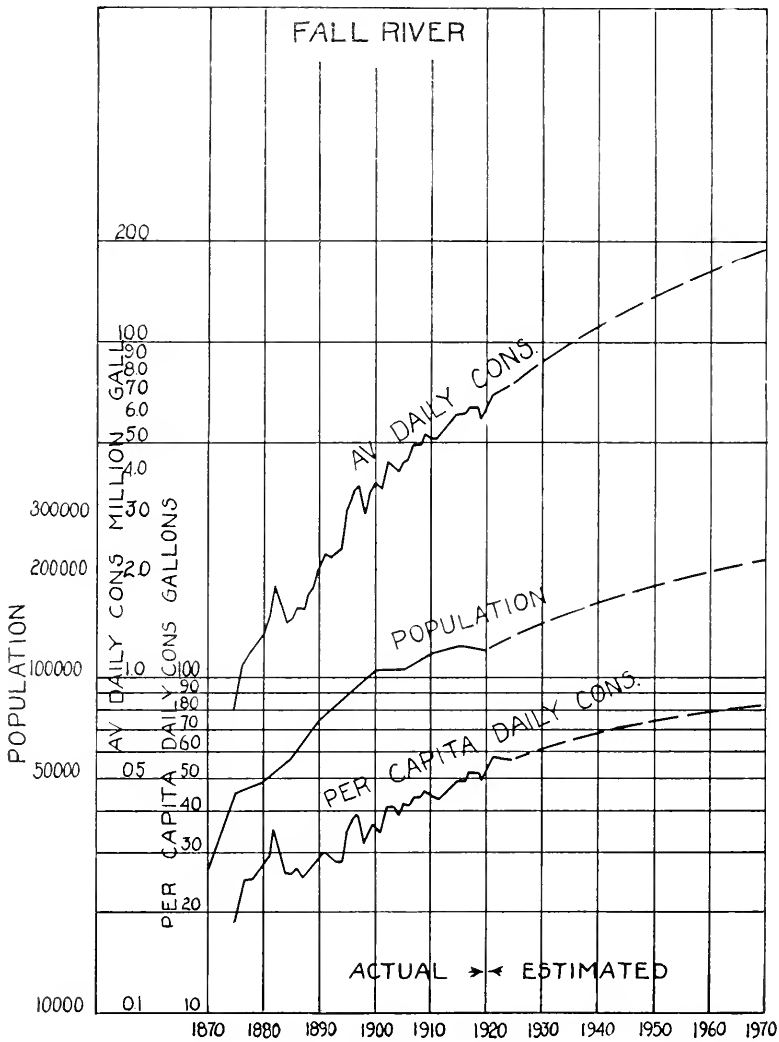


DIAGRAM No. 4.

For nearly 30 years preceding the construction of the intercepting drain on the western shore of the pond in 1916, the quantity of organic and mineral matter in the water of North Pond had gradually increased, but since 1916 conditions have improved and the mineral and organic contents of the water have materially diminished.

Sources of Additional Supply.

In any consideration of an additional water supply for Fall River, the first source to which attention is naturally directed is the South Watuppa Pond apparently so readily available for the use of the city. The first considerable number of analyses of the water from the South Pond was made in 1898, and the results of those analyses show that while at that time the water contained larger quantities both of mineral and organic matter than that of the North Pond, the difference was not as marked as it has since become, and there is little doubt that the quality of the water of the South Pond was originally the same as that of the North Pond. With the growth of population and industries along the shores of the South Pond and the diversion into it of water from populated areas within the watershed of North Pond, the water of South Pond has become more and more polluted until the quantity of mineral matter in the water is more than double that of North Pond, while the proportion of organic matter present is even greater. If this water were now to be used as a source of water supply for the city of Fall River, filtration would of course be necessary, since the cost of preventing its pollution would now be impracticable. But as the city grows filtration itself would become inadequate unless the inhabitants were satisfied to use a highly mineralized water, as compared with the water supplies of other cities in the State, and one which would still further deteriorate in quality. While the poor quality of the water and the probability of further deterioration are not the only and probably not the most serious objections to the use of this source for the water supply of Fall River, the use of so polluted a water with the likelihood of further deterioration is not to be justified if waters of better quality are available.

South Watuppa Pond being obviously unfavorable as an additional source of water supply, the city of Fall River has considered other sources in this region including several small local sources and Long Pond of the Lakeville group. These investigations show that it is impracticable to secure additional water supply from local sources except in small quantities and at excessive cost, considering the amount obtainable. They show further that in the end recourse would inevitably be had to a much larger supply which could be obtained most favorably from the Lakeville Ponds, provided they were then in a condition in which they could be used for water supply purposes or could be made available for such use at a reasonable cost.

Since recourse must eventually be had to the Lakeville Ponds, it would be far more economical for the city to secure its water supply from those ponds in the beginning than to expend the large sums of money needed for the development of small additional supplies from local sources, and in the not distant future a further large sum for obtaining a satisfactory water supply from the Lakeville sources, the cost of which would un-

doubtedly be greater than if these sources were taken and their purity secured at the present time and might be prohibitive.

It should be noted here that, while North Watuppa Pond is the only source of water supply of the city of Fall River, the city does not as yet control the flowage rights in the pond but that under an existing agreement the owners of this flowage can draw freely from North Watuppa Pond so long as the level of the water remains above 40 in. below full pond. Furthermore, these owners can continue to draw 5 million gallons per day when the surface of the pond falls below 40 in. below full pond and 2 million gallons per day when the water is at or below 55 in. below full pond, no matter to what level the water may be lowered. Obviously, unless this draft can be discontinued, the safe yield of North Watuppa Pond, which now amounts to about 7 million gallons per day when 5 ft. of the storage is utilized, might be very materially reduced in a dry period by draft by the mills, while if any new source of water supply should be introduced much of the water could be diverted from the pond for the use of the mills on the Quequechan River. To meet this difficulty, the city has appointed a commission to secure the flowage rights in North Watuppa Pond, and it is understood that negotiations are now nearly completed whereby the city will secure these rights of flowage and exclude further draft from the pond for the use of the mills.

Water Supply of New Bedford.

The city of New Bedford has had a variable growth, having even declined in population during the Civil War as already mentioned. In recent years its growth has been rapid and has extended to the adjacent towns of Dartmouth, Acushnet and Fairhaven, two of which, Acushnet and Dartmouth, are supplied with water from the New Bedford water works.

The circumstances affecting the use of water in this city are quite different from those at Fall River, since there is no large supply of fresh water like South Watuppa Pond available for industrial use, and practically all of the water for manufacturing and mechanical as well as domestic purposes must be taken from the municipal works.

The water works system of the city of New Bedford was introduced in 1869 and for many years the use of water per capita was large, but unnecessary use and waste has been checked in recent years by the metering of all services.

The quantity of water used in the city of New Bedford in each of the years since 1895, together with the population, the consumption of water per capita, the number of services and the per cent. of services metered, is shown in the following table:

Year.	Population.*	Average Daily Consumption (Gallons).	Per Capita Daily Consumption (Gallons).	No. of Services.	Per Cent of Services Metered.
1895	55 251	4 712 000	85	8 027	3
1896	56 689	5 259 000	93	8 117	1
1897	58 127	5 676 000	98	8 860	7
1898	59 566	5 908 000	99	9 014	8
1899	61 004	6 195 000	102	9 451	12
1900	62 442	6 318 000	101	9 280	15
1901	64 826	5 891 000	91	9 447	17
1902	67 210	6 372 000	95	9 612	18
1903	69 594	6 946 000	100	9 927	20
1904	71 978	7 022 000	98	10 166	21
1905	74 362	7 087 000	95	10 477	23
1906	78 820	6 917 000	88	10 764	26
1907	83 278	7 436 000	89	11 107	29
1908	87 736	7 488 000	85	11 516	31
1909	92 194	7 172 000	81	12 043	38
1910	96 652	7 864 000	81	12 769	48
1911	99 235	7 974 000	80	13 341	62
1912	101 818	8 281 000	81	13 613	73
1913	104 402	7 761 000	74	14 055	88
1914	106 985	7 432 000	69	14 407	96
1915	109 568	7 647 000	70	14 770	96
1916	111 898	8 516 000	76	15 126	96
1917	114 228	9 249 000	81	15 293	96
1918	116 557	9 716 000	83	15 376	99
1919	118 887	9 580 000	81	15 665	99
1920	121 217	10 085 000	83	15 962	99
1921	123 546	9 368 000	76	16 354	99

The consumption per capita was much smaller in the years of business depression, in 1914 and 1915, than before or since that time. A considerable reduction in the use of water again appears in 1921, a condition no doubt due to the mild winter and the excessive rainfall of the summer season by which that year was characterized and no doubt also by the prevailing business depression.

The future needs of the city in the matter of water supply have been estimated as follows: (See also Diagram No. 5).

Year.	Population.	Per Capita Daily Consumption (Gallons).	Total Consumption (Gallons).
1920†	121 217	83.2	10 085 000
1925	136 300	87.0	11 858 000
1930	151 700	90.6	13 744 000
1935	166 900	94.1	15 705 000
1940	181 900	97.5	17 735 000
1945	196 400	100.8	19 797 000
1950	210 800	104.0	21 923 000
1955	225 000	107.1	24 097 000
1960	239 100	110.1	26 325 000
1965	253 200	113.0	28 612 000
1970	267 100	115.8	30 930 000

*Populations for other than census years are estimated.
†Figures for 1920 actual, all others estimated.

As in the case of Fall River, the estimates may seem large but the favorable location of the city and the probable extension of its boundaries should be allowed for in any estimate of future growth.

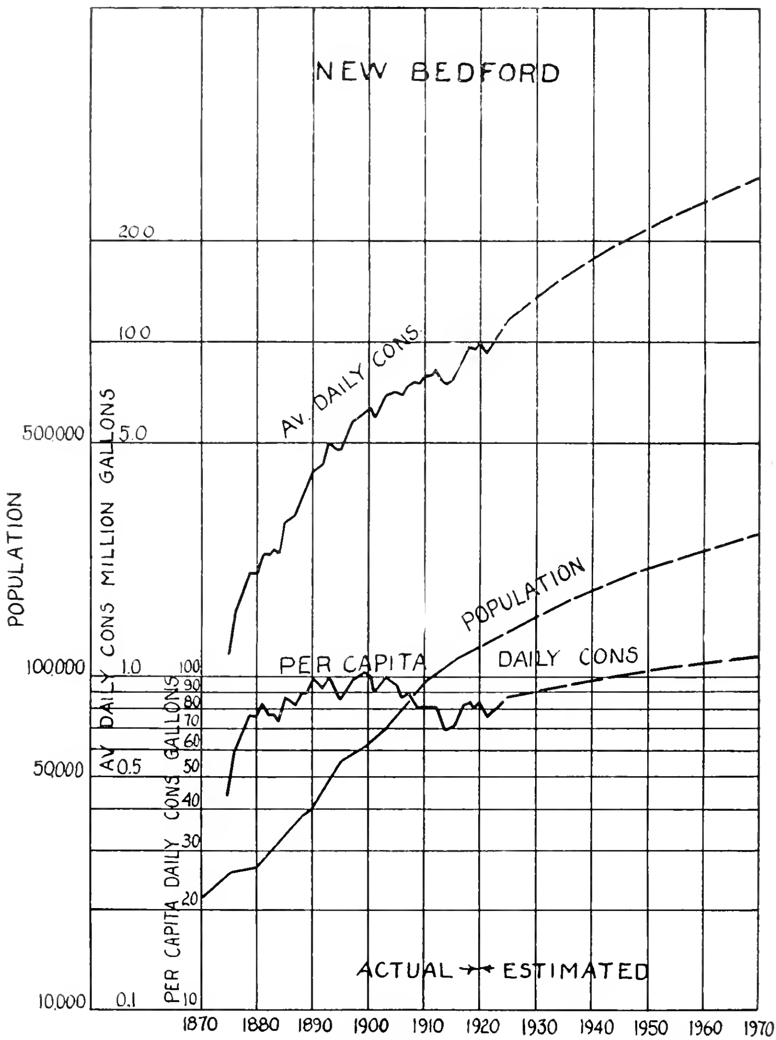


Diagram No. 5.

Sources of Supply.

The city of New Bedford was formerly supplied from a storage reservoir on the Acushnet River which furnished water which would now be regarded as of very poor quality for domestic use, being highly colored and heavily charged with organic matter, especially in the earlier years. In many respects the condition of the water of this reservoir is much the same

to-day. In 1886 the supply from the Acushnet Reservoir was supplemented by diversion into it through a canal, of water from Little Quittacas Pond, one of the Lakeville sources, and later on, in the year 1899, works were completed for supplying the city wholly from Little Quittacas Pond, supplemented with water flowing into it from Great Quittacas Pond. Under the authority of the Legislature these two ponds were separated from the remaining ponds of the Lakeville group and granted to the city of New Bedford as sources of water supply.

The area of the watersheds of these ponds, their area, average depths, and storage capacity are shown in the following table:

Pond	Area of Watershed Including Water Surface (Sq. Mi.).	Area of Water Surface (Sq. Mi.).	Storage Capacity (Mil. Gals.).
Great Quittacas Pond	11.42	1.81	4 990
Little Quittacas Pond	1.39	0.50	1 030

Quality of the Water of Great and Little Quittacas Ponds.

The water supplied by Great and Little Quittacas Ponds is soft and of good quality for domestic use. Soon after obtaining the right to the use of these ponds as sources of water supply, the city began securing the control of the lands within their watersheds and at the present time controls a large part of the watersheds of both Great and Little Quittacas Ponds and their tributaries. These lands were secured before the time when the use of the shores of ponds and banks of rivers as summer resorts had become as general as it is to-day and the lands were acquired at a small expense compared with the probable outlay that would now be necessary in case this opportunity had not been availed of at the right time. In consequence, there are very few dwelling houses within the watersheds of these ponds and the small population now living there is likely to diminish gradually as the remainder of these lands come under the control of the city. While these ponds furnish water which is soft and naturally of excellent quality for water supply uses, there are considerable areas of swamps on their watersheds, especially in the drainage area of Black Brook, the principal tributary of Great Quittacas Pond, and when it becomes necessary to use a greater portion of the storage than has been necessary in the past, the length of storage and its benefits in improving the quality of the water of tributary streams will be less effective than has hitherto been the case.

Safe Yield of Great and Little Quittacas Ponds.

In estimating the yield of these sources, it is necessary to allow for the retention of enough water in the ponds to secure sufficient benefit from storage to prevent serious deterioration in the quality of the water; but assuming that these ponds will be drawn down to a level of about 12 ft. below high water, using 80 per cent. of the storage capacity, their safe yield would be about 12 million gallons per day. This quantity is only about 28 per cent. in excess of the consumption of water in the city in 1921. The drawing down of the storage to such an extent would probably affect unfavorably the color and other qualities of the water.

Additional Water Supply.

The city of New Bedford at the present time supplies water to the adjacent towns of Dartmouth and Acushnet and to a small area in Freetown, the quantity used in Dartmouth in 1921 having been 56 000 gal. per day and in Acushnet 40 000 gal. per day. The city is also authorized to sell water to Lakeville.

The old storage reservoir is still available for use in emergencies. This reservoir has an area of about 300 acres and a storage capacity of about 400 million gallons, and receives the flow from a watershed of about 5.3 sq. mi. Its safe yield is probably about 3 600 000 gal. per day. The water of this reservoir has always been high in color and it contains a larger amount of organic matter than is found in the waters of most of the natural ponds in this region. This water could probably be used in an emergency if proper sanitary inspection were maintained within the watershed, but its quality at the present time would no doubt be objectionable unless filtered, and the expense of making it satisfactory for the use of the city would be large in proportion to the quantity of water obtainable.

An additional supply can be obtained more readily from Assawompsett Pond if approved by the Legislature than from any other source, since it is easily practicable to divert water from Assawompsett Pond into Great Quittacas Pond, these sources being separated only by a narrow causeway.

Water Supply of Taunton.

The city of Taunton had a population in 1920 of 37 137. This city has grown more slowly than New Bedford or Fall River and in one census period, between 1900 and 1905, the population slightly declined.

A water supply was introduced in the year 1876. The quantity of water used in the city of Taunton since 1895, together with the population, the consumption of water per capita, the number of services and the per cent. of services metered, is shown in the following table:

Year.	Population.	Average Daily Consumption (Gallons).	Per Capita Daily Consumption (Gallons).	No. of Services.	Per Cent. of Services Metered.
1895	27 115	1 153 000	43	3 843	36
1896	27 899	1 179 000	42	3 955	36
1897	28 683	1 250 000	44	4 090	38
1898	29 468	1 302 000	44	4 233	38
1899	30 252	1 458 000	48	4 372	40
1900	31 036	1 645 000	53	4 502	41
1901	31 022	1 738 000	56	4 618	42
1902	31 008	1 512 000	49	4 698	44
1903	30 995	1 531 000	49	4 753	45
1904	30 981	1 771 000	57	4 837	45
1905	30 967	1 910 000	62	4 914	46
1906	31 625	1 915 000	61	4 983	46
1907	32 284	2 114 000	66	5 043	47
1908	32 942	2 247 000	68	5 194	48
1909	33 601	2 168 000	65	5 237	50
1910	34 259	2 150 000	63	5 344	50
1911	34 639	2 233 000	64	5 301	53
1912	35 020	2 366 000	68	5 420	54
1913	35 400	2 338 000	66	5 526	56
1914	35 781	2 373 000	66	5 635	58
1915	36 161	2 222 000	61	5 755	59
1916	36 356	2 480 000	68	5 846	61
1917	36 551	2 792 000	76	5 930	62
1918	36 747	3 154 000	86	5 979	63
1919	36 942	3 090 000	84	6 013	65
1920	37 137	3 395 000	91	6 091	71
1921	37 333	3 237 000	87	6 170	77

It will be noted that the consumption of water per capita has increased gradually notwithstanding the steadily increasing percentage of metered services.

The probable future needs of the city of Taunton in the matter of water supply have been estimated as follows: (See also Diagram No. 6).

Year.	Population.	Per Capita Daily Consumption (Gallons).	Total Consumption (Gallons).
1920†	37 137	91.4	3 394 000
1925	40 000	93.9	3 756 000
1930	42 900	96.4	4 136 000
1935	45 800	98.9	4 530 000
1940	48 700	101.4	4 938 000
1945	51 600	103.9	5 361 000
1950	54 400	106.4	5 788 000
1955	57 200	108.9	6 229 000
1960	60 000	111.4	6 684 000
1965	62 800	113.9	7 153 000
1970	65 600	116.4	7 636 000

* Populations for other than census years are estimated.

† Figures for 1920 actual, all others estimated.

Sources of Water Supply.

The city of Taunton formerly obtained its water supply from a filter gallery near the banks of the Taunton River supplemented with water taken directly from the river. Subsequently, in 1894, works were com-

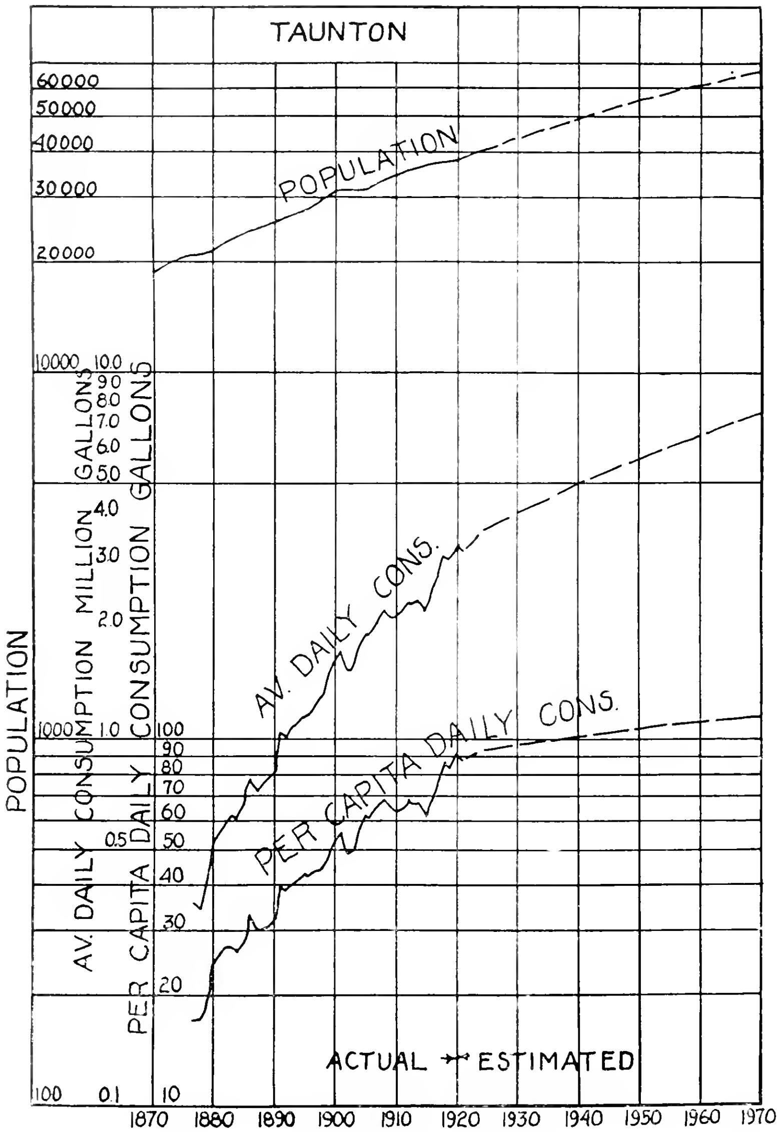


Diagram No. 6.

pleted for taking water from Elder's and Assawompsett Ponds of the Lakeville group. At the present time water is pumped from Assawompsett Pond at a pumping station located on its westerly shore about half a mile

north of the outlet of Long Pond into Elder's Pond, whence it flows by gravity to a pumping station in Taunton from which it is supplied to the city. The water supplied in this way is soft, very low in color and of excellent quality for domestic use. The quantity of water used from these ponds by the city of Taunton is only a small portion of their safe yield in a dry period.

The city of Taunton has acquired all the lands about Elder's Pond and considerable areas along the shore of Assawompsett Pond for the protection of its water supply, but the amount so controlled is small in proportion to the entire shore line of Assawompsett Pond and its tributaries, Long and Pocksha Ponds.

The Lakeville Ponds as Sources of Water Supply for The Joint Use of The Cities of Fall River, New Bedford and Taunton and Other Municipalities in Their Vicinity.

In connection with the investigation of the water supply needs and resources of the Commonwealth, under the provisions of Chaper 49 of the Resolves of 1919, the available information relative to the area and capacity of the Lakeville Ponds was collected in coöperation with the authorities of New Bedford and Taunton and was supplemented with such further surveys and soundings as were necessary to determine the area, depth and capacity of all the larger lakes, the areas of their watersheds, the extent of the swamps thereon, and the number of dwelling houses, cottages and other structures within their watersheds. From that report the following table is taken showing the area, capacity, elevation of water surface and area of watershed of each of these ponds:

	Area of Watershed Including Water Surface. (Sq. Mi.).	Area of Water Surface. (Sq. Mi.).	Storage Capacity. (Mil. Gals.).	Elevation at Which Data Are Taken.* Boston City Base.
Long Pond	21.22	2.80	5 730	61.45
Assawompsett and Pocksha Ponds	13.17	4.20	8 900	60.79
Great Quittacas Pond	11.42	1.81	4 990	60.07
Little Quittacas Pond	1.39	.50	1 030	59.57
Elder's Pond	.53	.22	692	93.54
Totals..................	47.73	9.53	21 342	....

The ponds are divided naturally into two groups each of which is tributary to Assawompsett Pond, the largest and under original conditions the lowest of all. The waters of Elder's Pond flow naturally into Long Pond and thence into Assawompsett Pond near its southerly end, while on the easterly side of the watershed the waters of Little Quittacas Pond flow naturally to Great Quittacas Pond and thence in times of high flow

*These elevations, observed on March 18, 1920, are the highest recorded during the progress of the surveys.

into Pocksha Pond which is practically an arm of Assawompsett Pond on its easterly side. The Nemasket River, which forms the outlet of the entire group, flows northerly from the northerly end of Assawompsett Pond. The conditions affecting these ponds have been materially changed since the cities of New Bedford and Taunton began drawing water from them, and in dry seasons under present conditions little or no water overflows from Great Quittacas Pond into Pocksha Pond and no water runs from Elder's Pond to Long Pond. A dam has been constructed by the city of New Bedford, as authorized by the Legislature, between Great Quittacas and Pocksha Ponds to prevent water from the latter flowing into Great Quittacas Pond except in times of high flow, but the surplus water of Great Quittacas Pond discharges into Pocksha Pond.

Quality of the Water.

The water of all the Lakeville Ponds is very soft and naturally of excellent quality for water supply uses. The water of Long Pond, which receives the flow of nearly half the aggregate drainage area of the ponds, is usually considerably colored, but in the remaining ponds the color is not at any time excessive and the waters supplied from Little Quittacas Pond and Elder's Pond to New Bedford and Taunton, respectively, are among the most desirable waters of the State. The comparatively low color of the water of most of the ponds is in marked contrast to that of their chief tributaries, some of which are very highly colored. This high color is due to the passage of the water through swamps of which the watersheds of these ponds, like most watersheds in this part of the State, contain extensive areas, and it will be necessary in order to maintain and improve the quality of the water of the ponds to drain or otherwise better the conditions in the swamps. These swamps have an aggregate area of about 5.34 sq. mi., or a little over 3 400 acres, and fall naturally into two groups. One includes those which are adjacent to the streams tributary to the ponds and includes the swamps adjoining Black Brook, Fall Brook and a brook flowing from Elder's Pond which contain in the aggregate some 2 400 acres. The brooks which drain these extensive swamps have sufficient fall for the most part to allow of their adequate drainage, and a great improvement in the color of these waters could no doubt be effected thereby. The second group of swamps includes those which are adjacent to the shores of the ponds themselves with an aggregate area of a little over 1 000 acres and a total frontage along the ponds of about 41 800 ft. These swamps are about 48 in number and occupy about 23 per cent. of the shore line of the ponds from which they extend back varying distances of from 100 to 4 600 ft. Their surfaces lie, for the most part, little above the normal level of the high-water surfaces of the ponds, but by drainage, diking or other means they can either be drained or so treated as to prevent them from affecting seriously the quality of the waters of the ponds.

The high color of the waters of the tributaries is rapidly reduced when exposed to sunlight and other influences in their passage through the ponds, in which the color is largely removed by bleaching, by dilution with the rainfall and with water not affected by swamps, and by other actions which take place in large storage reservoirs. When the water finally reaches the outlet of the last pond of the series the color is reduced to a comparatively small amount.

The extent of this improvement depends largely, no doubt, upon the time which elapses in the passage of the water through the ponds, and if the water in storage should be drawn to too low a level the colored water of the tributaries could pass through more rapidly and there would be less improvement than at the present time. For this reason, while it is probable that for many years the draft on the ponds by the cities in question would affect but little the color of the water, it is important that as the draft increases the color of the waters of the tributaries shall be reduced by drainage so far as is necessary and practicable to prevent them from raising the color of the water in the ponds to an objectionable degree.

Protection of the Purity of the Water of the Lakeville Ponds.

The watersheds of the Lakeville Ponds contain no villages of considerable size and no important manufacturing establishments producing foul wastes are found within their limits. The permanent population is, in fact, very small and widely scattered and danger of pollution from it nearly negligible; but while the population living permanently within the watersheds of these ponds is very small compared with their area at the present time, there is a considerable and growing population in the cottages and camps about the shores of Long, Pocksha and Assawompsett Ponds, and, while a small area is under public control along the shores of Assawompsett Pond, the remaining lands are still in private ownership and are open to settlement. The total number of dwelling houses, camps, and other buildings located within the watersheds of these ponds amounted at the time of the recent surveys to about 342. A classification of the lands within approximately 1 400 ft. of these ponds is given in the following table:

Land.	Acres.
Cottage and camp lots	228
Private estates and parks	171
Farm land	92
Heavily wooded land	609
Scrub land	1 060
Swamp land	836
Land owned by municipalities	108
Total	3 104

The assessed valuation of the buildings and land privately owned and included in the foregoing table is estimated as follows:

Buildings	$385 000
Land	304 000
Total	$689 000

These large natural reservoirs, lying at the doors of the principal municipalities in southeastern Massachusetts, are a great advantage to these cities and towns when the cost of artificial storage in this region is taken into consideration. The cost of construction of suitable artificial reservoirs for these cities would be great and the further cost of improving the quality of their waters sufficiently to equal that obtainable at present from the Lakeville Ponds would require a very large outlay either for the preparation of the reservoir site or for purification works, together with the cost of operation and maintenance. Moreover, in order to secure a quantity of water equal to the yield of the Lakeville Ponds and their tributaries it would be necesary, in all probability, especially if each city should undertake the development of independent supplies, to develop and use two or more watersheds for the purpose.

On the other hand, the Lakeville Ponds, the largest natural ponds in the State, are reservoirs of very large capacity, already in existence, well adapted for the purpose, and requiring no costly dams or other works to make them available for water supply uses beyond a regulating weir at the outlet of Assawompsett Pond. An idea of what it might cost these cities to construct reservoirs of similar size may be gathered from a consideration of the cost of some of the artificial reservoirs in the State which furnish water of similar quality. The Sudbury Reservoir, which holds about half the aggregate amount of water contained in Assawompsett, Long and Pocksha Ponds, cost, exclusive of water damages and of the cost of works for protecting the quality of the water, $2 923 152.96 or about $403 per million gallons. If reservoirs of equal size had to be constructed artificially for the water supplies of Taunton, Fall River and New Bedford, the cost at the same rate would be from 5 to 6 million dollars. If the cost were no greater proportionately than that of the Borden Brook Reservoir of the city of Springfield, constructed under more favorable conditions than are found in southeastern Massachusetts, the construction of reservoirs of the size of the Lakeville Ponds would cost $1 250 000 even at pre-war prices; but the water of Borden Brook Reservoir is subsequently filtered.

In the presence of these great natural ponds, available for water supply uses in their immediate neighborhood, the cities of southeastern Massachusetts are favored above other cities of the State. If these cities can secure united action they can obtain the right to use the Lakeville Ponds

as their future sources of water supply. By uniting in securing and protecting these lakes they will obtain storage reservoirs of great size, requiring no outlay for construction, which lie close to their doors and which with comparatively little outlay will furnish unpolluted water of excellent quality for the use of their inhabitants for a very long time in the future without treatment of any kind. That so remarkable an opportunity will be neglected through mutual distrust or differences as to minor matters of detail such as methods of procedure, or of control or operation of the works is, of course, not to be thought of; but failure to grasp this great opportunity in season and to make this water supply available to the cities in the most reasonable and practicable way may result in a serious increase in the cost of the project and perhaps in preventing their development in such a way as to secure the most satisfactory water supply obtainable from these sources.

THE WATER SUPPLY OF FALL RIVER.

BY H. K. BARROWS.*

[September 14, 1922.]

Seven years ago, in September, 1915, the writer presented a paper at the Annual Convention of this Association entitled "Improvements to the Water Supply of the City of Fall River." At that time most of the improvements described were still in process of construction. The purpose of this paper is to complete the description of these works and describe some of the further projects, particularly for additional water supply, which have been studied since that time and are now nearly at the construction stage. Many of the mills in Fall River utilize the waters of Quequechan River, supplied from the South Watuppa Pond, and as the problems involved in assuring an ample water supply for these mills are closely connected with those of the municipal water supply, this paper will include a description of the plans for the improvement of the Quequechan River.

As described in the previous paper, the history of the municipal water supply of Fall River has been most interesting and has involved some perplexing questions considered at much length and over many years in the courts. Following is a brief summary of legislation, decisions, etc., as described in the previous paper, bringing matters up to about 1913.

North Watuppa Pond — Summary of Legislation, etc., to 1913.

1874. Water Act authorizing use of 1 500 000 gal. per day by city.

1880. Suit by Watuppa Reservoir Co. for damages under Act of 1874. Company awarded $70 000.

1886. Act authorizing 1 500 000 gal. per day additional use of water by city.

1888. Suit of Watuppa Reservoir Co. for additional damages not sustained. Chief Justice Morton held that "State had right to use the waters of the great ponds, etc., without compensation."

1891. Supreme Court reversed decision of 1888 because Watuppa Reservoir Co. were successors in title to grantees of Plymouth Colony.

1892. Agreement made by city and Watuppa Reservoir Co. whereby Company can use unlimited water to 40 in. below full pond. City can use water for water supply, but does not control storage.

1895. Watuppa Reservoir Commission established by city, to control and protect its water supply.

* Consulting Engineer, Boston, Massachusetts.

1897. City took by condemnation entire North Pond to "preserve and protect water supply" — but in accordance with agreement of 1892.

1907. Regulations protecting North Pond made by State Board of Health.

1909. Act authorizing city to borrow money for construction of works and protection of water supply. *Intercepting drain* built under this act, (in 1915).

The most important work under construction for the improvement of the water supply in 1915 was that of the intercepting drain on the west shore of North Watuppa Pond, built for the purpose of preventing drainage from various populated districts entering the North Pond. Details of the different sections of this drain are presented in the previous paper, the entire length being about 14 000 ft., mostly of reinforced concrete, open section, varying in width from 6 to 10 ft.

The contract for this work was let early in 1915 and the work completed by about September 1, 1915, the total construction cost approximating about $190 000. Some of the more interesting details of cost are appended to this paper.

This intercepting drain was put in commission in January, 1916 and has been in use since that time. It was an excellent piece of construction work and the lapse of some seven years shows the concrete in practically as good condition as when built. (See Figs. 1-4 inclusive.)

As a considerable part of this drain is open section, whereby a very substantial saving in first cost resulted, it has required some annual cost of maintenance to clear out stones and debris, and occasionally some ice, always likely to accumulate in a structure of this kind. This has cost about $100 annually, as an average cost for the first five years.

Another feature which has been of interest in the operation of this drain is that of ice effect. The winters of 1918 and 1920 were unusually severe, resulting in solid ice of considerable thickness forming in the open section of the drain. Careful watch was kept of this situation, particularly in 1918, to prevent any possible ice jams and overflow of the drain, but in both 1918 and 1920 the thick ice which formed gradually softened and went out in the early spring without bad effect.

The sanitary results obtained by the operation of this intercepting drain have been excellent, as shown by the following table, giving the results of bacteriological examinations before and after its construction. The marked pollution of the waters of Highland, Terry and Cress Brooks, all diverted by the drain, is apparent, as is also the effect of this pollution upon the quality of water at the water-works intake, before the drain was built.

King Philip and Blossom Brooks lie on the easterly side of the pond and still contain considerable areas not yet acquired by the City and which eventually must be taken.

Nat and Ralph Brooks are badly polluted and must be diverted to the South Pond as further noted.

FIG. 1 — JUNCTION OF 10 FT. OPEN AND CLOSED SECTIONS. FALL RIVER INTERCEPTING DRAIN — OCTOBER, 1915.

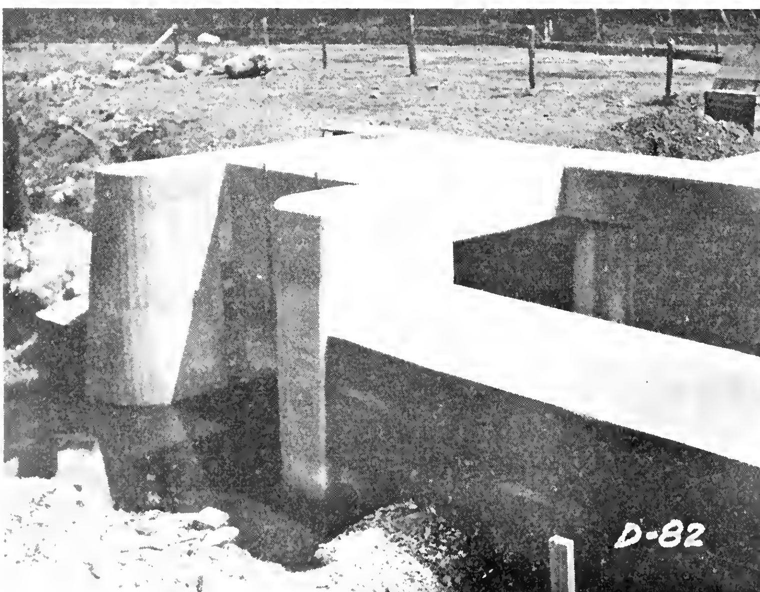


FIG. 2 — HIGHLAND BROOK INTAKE. FALL RIVER INTERCEPTING DRAIN — AUGUST, 1915.

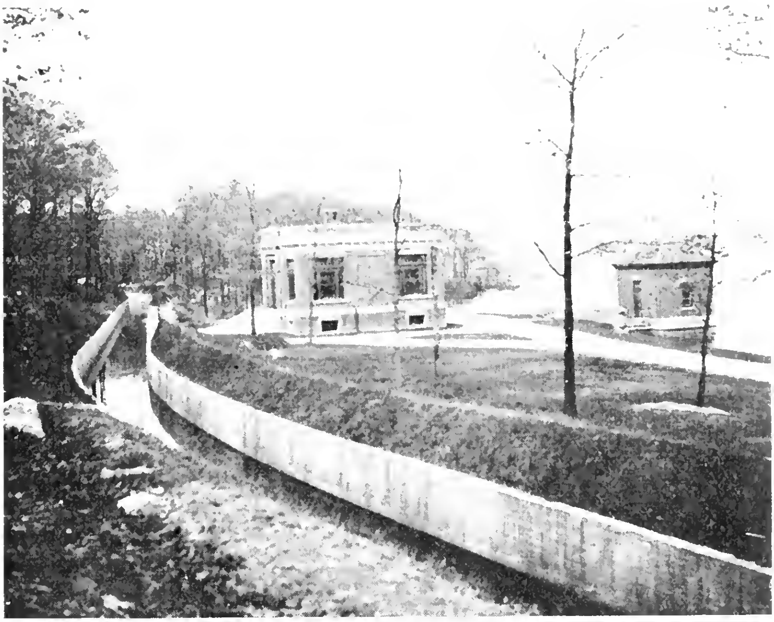


FIG. 3. — AUXILIARY PUMPING STATION AND INTAKE, ALSO 10 FT. OPEN SECTION OF INTERCEPTING DRAIN — NOVEMBER, 1921.

FIG. 4. — 8 FT. OPEN SECTION OF INTERCEPTING DRAIN — NOVEMBER, 1921.

NORTH WATUPPA POND — BACTERIOLOGICAL EXAMINATIONS OF WATER BY CITY DEPARTMENT OF HEALTH — DR. J. H. WALSH, BACTERIOLOGIST.

Before 1915, (construction of Intercepting Drain).

	Excellent.	Reasonably Good.	Doubtful.	Extremely Doubtful.
Intake at Pumping Station	37%	47%	11%	5%
Highland Brook	0	7	50	43
Terry Brook	0	8	42	50
Cress Brook	0	0	41	59
King Philip Brook	27	56	13	4
Blossom Brook	20	62	18	0
Ralph Brook	0	19	63	18
Nat Brook	0	0	40	60

During 1920

	Excellent.	Reasonably Good.	Doubtful.	Extremely Doubtful.
Intake at Pumping Station	76%	24%	0%	0%
Highland Brook, Terry Brook, Cress Brook	Water diverted to South Pond			
King Philip Brook	40%	43%	9%	8%
Blossom Brook	13	51	23	13
Ralph Brook	11	35	31	23
Nat Brook	0	23	40	37

Note — Percentage is of number of samples examined.
Classification as follows: —
Excellent — No Colon in 10 c. c.
Reasonably good — Colon in 10 c. c. and not in 1 c. c.
Doubtful — Colon in 1 c. c.
Extremely doubtful — Colon in 1/10 c. c. and less.

The construction of this intercepting drain was following the policy of the Fall River Reservoir Commission (consisting of the Watuppa Water Board, acting with the Mayor and City Engineer), which has been to either acquire all land within the drainage area of North Watuppa Pond or, where the conditions of growth and population made this too expensive, to divert these waters to South Watuppa Pond, where they would still be useful for mill water-supply purposes. (See Fig. 5.) In carrying out this policy some 3 300 acres of land around the South Pond has been purchased by the city at a cost in excess of $300 000 as well as the construction of the intercepting drain just described.

There still remains an area of a little over half a square mile constituting a portion of the village of North Westport on the southeasterly shore of the pond, and included in portions of the drainage areas of Nat and Ralph Brooks, which must be diverted to the South Watuppa Pond. Surveys and plans for this work were made during 1915–17 and this project is now ready for construction. It involves the construction of an earth fill dam about 1 600 ft. long and 12 ft. high, with a cut off of sheet piling, across the inlet of the pond in this vicinity, with a 48-in. outlet conduit to South Watuppa Pond about 225 ft. long. The waters of a consid-

erable portion of Ralph Brook will be brought by means of a 15-in concrete conduit, about 2 700 ft. long, to the pond back of this diversion dam and also discharged into the South Watuppa Pond. The total

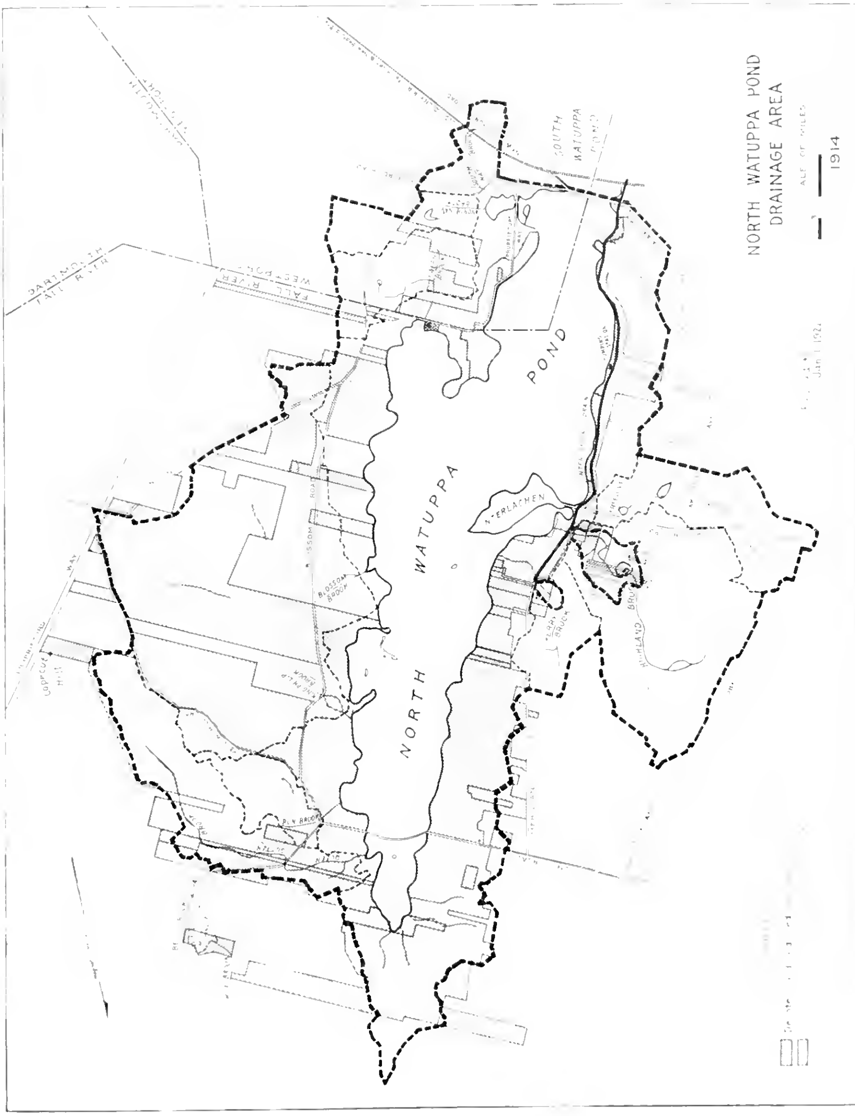


FIG. 5.

estimated construction cost of this work based on approximate normal costs, is about $75 000. At present this cost would probably exceed $100 000. The sanitary conditions on portions of Nat and Ralph Brooks are bad, as will be noted by the data in the previous table, although the entrance of these brooks is at a very considerable distance from the

water-works intake. The construction of this project will therefore proceed as soon as costs become somewhat further stabilized.

The other several improvements under way in 1915, which included (1) a 7 million gal. Platt high duty pump at the main pumping station, (2) an auxiliary pumping station with an 8 million gal. motor operated centrifugal pump, (See Fig. 3.) (3) a 36-in. force main from the pumping

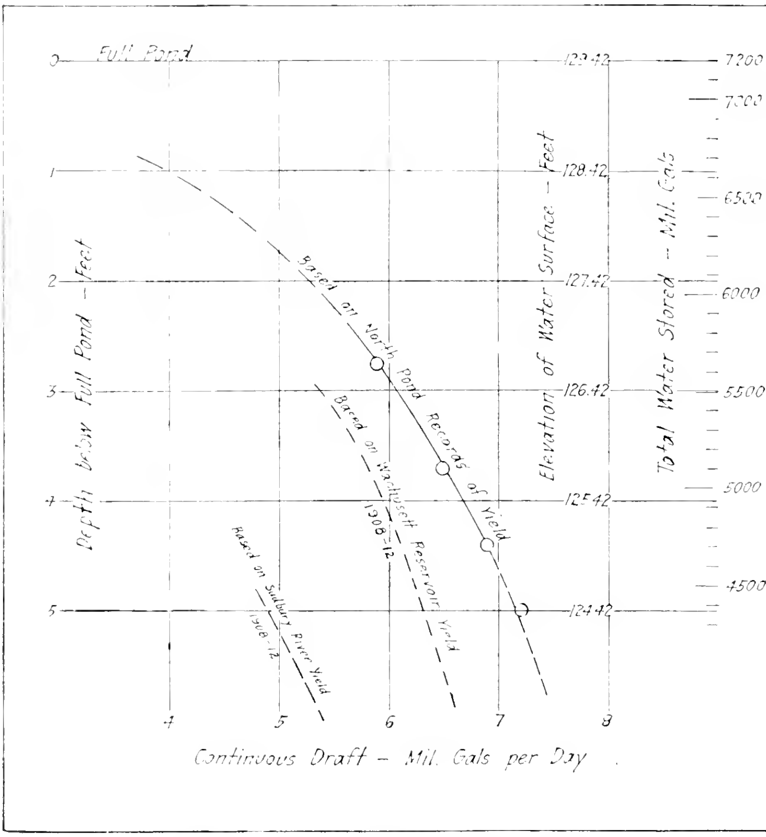


FIG. 6. — YIELD OF NORTH WATUPPA POND.

station at Eastern Ave. (a distance of about 3 400 ft.) have all been carried out, at a total cost in the vicinity of $100 000. In 1918 the main pumping station was fireproofed by constructing a new steel and concrete floor finished with tile and building brick walls faced with white enamel brick for a height of 10 or 12 ft. The plastering above this level, as well as the interior of the station generally, was also renovated and painted, the total cost of the work aggregating about $10 000. The roof was also re-slated, at a cost of about $3 200, so that the main building, built in 1873, is now in excellent condition.

During the period of the war of course only necessary construction was carried on, practically that just described, with some necessary pipe extensions, but since 1916 a careful and thorough investigation has been made of the question of additional water supply.

The drainage area of North Watuppa Pond when the Nat and Ralph Brook diversions are completed will total 8.54 sq. mi. of which 2.82 sq. mi. or about 33 per cent., (an unusually large proportion, resulting in large evaporation losses) consists of the area of the pond at high water level. Careful studies of the safe yield of the pond have been made, the results of some of these studies being shown on the accompanying diagram. (See Fig. 6.) Approximate records of the yield of the pond have been kept, more or less completely, from 1899 to the present time. For the years 1899 to 1901, inclusive, accurate measurements by means of a weir were made of water passing the Narrows, that is, from the North to the South Pond, and accurate pumping records of water used by the city have been kept over the entire period. Since 1911 the discharge at the Narrows has been measured fairly accurately by means of frequent current meter measurements made under the direction of the City Engineer. For the period 1902–1910, inclusive, records of the height of the pond and of the gate conditions at the Narrows have been kept, which serve as a basis for a rough estimate of discharge. Unfortunately the dry period of 1908–1912 is thus covered chiefly by the poorer records, making the determination of safe yield from these records somewhat questionable. On the diagram (Fig. 6) the safe yield of the pond based upon these records is shown for different amounts of storage utilized. Similar curves are shown based on the yield of the Wachusett Reservoir and that for the Sudbury River from 1908 to 1912. In this connection note that the average rainfall at Fall River is in the vicinity of 44 in., while that for the Wachusett Basin is about 45.3 in. and that for the Sudbury 44.6 in. The available storage capacity of the North Pond in the first 5 ft. of draft, as will be noted, is about 2 800 million gallons or some 330 million gallons per sq. mi. of drainage area, and keeping in mind the form of these curves, the increase in safe yield obtained by further pulling down the pond is small. Taking into account the present limitations in draft due to the elevation of intakes at the pumping stations, as well as the undesirablility of exposing large areas of muddy shores in certain parts of the pond it does not appear desirable to count on more than 5 ft. or 6 ft. at the most, of depth, for which amount of storage the safe yield of the pond is between 6.5 and 7 million gallons per day.

The consumption of water by the city is shown on Fig. 7 and, as will be noted, for the year 1921 this consumption reached an amount of 7 million gallons per day, or just about the safe yield of the pond, so that the necessity of providing an additional supply is apparent. In 1916, a Water Act was obtained by the city which gave it authority to make investigations and to use as a water supply any water source within the limits of Fall River and also that of Mill Brook in the town of Freetown, this being along

lines suggested by the State Department of Health in reports prior to that time. Under this Act, surveys and investigations were made during 1916, covering possible sources and including, in addition to Mill Brook, which lies northerly from North Watuppa Pond, the possible use of Bread

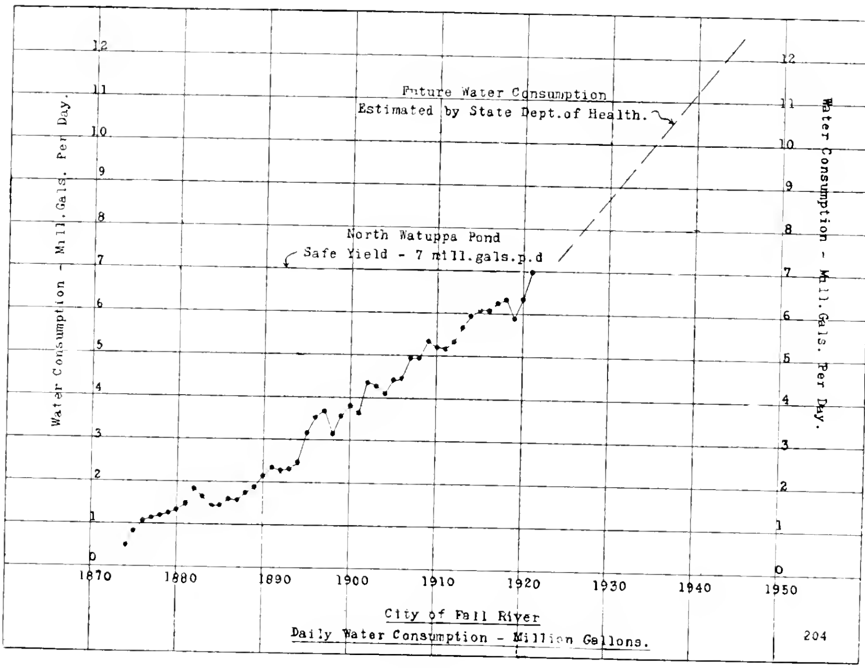


FIG. 7.

and Cheese Brook, a small stream lying easterly from the pond, and Copecut River lying northeasterly — all of which could be adapted to provide a further supply which would flow by gravity into North Watuppa Pond. The preliminary results of these investigations are given in the accompanying table:

COMPARISON OF PROJECTS FOR ADDITIONAL WATER SUPPLY.*

Item.	Project and Drainage Area.		
	Mill. (3.35 Sq. Mi.).	Bread and Cheese (2.65 Sq. Mi.).	Upper Copecut (3.13 Sq. Mi.).
Cost (not including water rights)	$438 100	$491 000	$751 900
Safe yield (mil. gal. per day)	2.90	2.40	2.30
Cost per mil. gal. (per day safe yield)	$151 000	$204 000	$327 000
In conjunction with full use of North Pond would give city a safe supply until about	1938	1935	1934

* Report of November 17, 1916 — H.K.B.

The results shown therefore led to the making of test borings at the Mill Brook dam site and a more accurate determination of the cost of this project during the first half of 1917. The results of these further investigations indicated that the preliminary figures of cost were ample and that the construction cost of the Mill Brook project should not exceed about $375 000 on the basis of approximate normal costs, not including the cost of any water rights, the latter chiefly comprising use of water at the Crystal Spring Bleachery in the town of Assonet.

Before the completion of these investigations the State Department of Health advised the consideration of a supply of water from Long Pond lying some ten miles east of the city and a careful investigation was also made of the use of this pond, including a pumping station and pipe line to North Watuppa Pond. This project proved to be much greater in first cost than the Mill Brook, owing largely to the necessary takings of land and buildings around Long Pond. Furthermore, the proportionate cost was greater than for the Mill Brook supply, viz. per million gallons and daily capacity, as indicated by the following cost estimates:

ESTIMATED COST OF 3 MILLION GALLONS PER DAY WATER SUPPLY FROM LONG POND.

(Based upon normal cost conditions.)

Pipe Line	$250 000
Intake, Pumping Station, Equipment, etc.	40 000
Cost of Pumping	240 000
TOTAL COST (exclusive of land and water rights or control works)	$530 000

The State Department of Health, however, took the attitude that it was time to begin the development of the larger supply in the Lakeville Ponds and did not approve the further consideration of the Mill Brook supply. They further recommended that full control of the North Watuppa Pond be obtained by the city before any further action was taken toward obtaining an additional supply.

As explained in the paper of 1915, the North Watuppa Pond is not a "Great Pond" legally, as the suit of 1891 established that the Watuppa Reservoir Company, an association of various mills along Quequechan River, were successors in title to grantees of Plymouth Colony, to whom the land under and on both sides of the outlet of the pond was conveyed on March 5, 1680, to Church, Gray and others for £1 100. This grant, known as the Pocasset Grant, included all of the South Pond and about half of the North Pond. Since 1892 the city has been working under an agreement with the mills whereby it can use an unlimited amount of water from the North Pond for purposes of municipal water supply, but, on the other hand, the mills can also make use of this water without restriction down to a level of about 40 in. below full pond. One of the other

terms of this agreement is the so-called "Tax Rebate," whereby taxes on the water power of these mills are rebated by the city — this amounting to some \$6 000 or \$7 000 per year, depending on the tax rate. Under this agreement of 1892 it is obvious that the city had only partial control of the storage of water in the North Pond. Consequently for the last few years it has escaped a shortage of water only by good luck.

The Water Act of 1916 provided for the taking of the North Pond rights by condemnation, if necessary. It was felt, however, that a settlement might be effected by agreement, and negotiations were accordingly carried on during the years 1919 and 1920, finally resulting in an agreement between the mills and the city which was accepted by the City Council in March, 1920. This agreement provided, in brief, that the agreement of 1892 with the mills be terminated and that the city should have full control and rights in the North Watuppa Pond upon payment to the Watuppa Reservoir Company of the sum of \$75 000, and further provided that the operation of the Quequechan River improvement whereby the water supply of the South Pond would be better conserved for the use of the mills, should also be carried out.

The improvement of the Quequechan River is a project which has been before the city for many years. While the mills have had the control of the South Watuppa Pond, no attempt has been made to adequately utilize its storage capacity, with the result that at various times within the last dozen years the waters of the Quequechan River have become so low that not only has the river itself been most unsightly, but the mills have in many cases had to shut down for lack of water to operate them.

These constantly recurring conditions becoming well-nigh intolerable finally resulted in legislation and general investigation of the matter of improving Quequechan River, for which plans were submitted in 1915 to the City Council, providing, in brief, for the filling in of the river channel and flats and the handling of the river water in a three level reinforced concrete conduit in addition to a general system of sewers and drains for the district. This scheme of improvement involved so great a cost, however, (about \$3 000 000 in first cost) that the plans were not accepted by the City Council and in 1916 a new Quequechan River Commission was created and plans prepared on a more economical basis. In brief, these provided for retaining the greater portion of the present river basin and dredging it to greater depth, as well as a district sewer system, while the storage capacity of the South Watuppa Pond is to be utilized by a dam and pumping station at the Sand Bar at the outlet of the pond. The first cost of this scheme as first proposed approximated \$800 000 (on the basis of normal costs), which was increased to a little under \$1 000 000 to meet certain requirements of the State Department of Health.

Plans for this work were accepted by the City Council as a part of the agreement of 1920 between the city and the mills, this agreement providing that the Sand Bar Dam and pumping station for the control of the waters

of the South Pond should be built and put in operation as one of the stipulations relative to the taking of the North Pond. The City Council authorized a bond issue of \$200 000 in 1920 to begin this work, as well as \$75 000 to pay for the North Pond water rights, with the idea of promptly carrying out the terms of this agreement with the mills. Contract plans for the Sand Bar Dam and pumping station were completed in 1920 and bids received for this work in December of that year. Opposition from certain mill interests on South Watuppa Pond toward the carrying out of this project developed early in 1921, with the result that no progress was made during that year.

During the winter of 1921–22 additional legislation transferred the duties of the Quequechan River Commission to the Watuppa Reservoir Commission in order that this work may be promptly carried out and the full control of the North Watuppa Pond obtained by the city, as well as an adequate water supply provided for the mills, and the Reservoir Commission now has these matters in hand.

During 1920–21 the State Department of Health made a general investigation to determine the best method for the joint use of the Lakeville Ponds (a group of large ponds lying some 10 miles northeast of Fall River and including Long Pond, already mentioned) by the towns and cities in that vicinity, reporting on this matter to the Legislature in January, 1922. In brief, this report stated, "That the improvement and protection of these great natural reservoirs can best be secured by united action of the municipalities interested, the cost to be divided proportionately among those interested. This purpose could be effectively carried out, no doubt, by the creation of a water-supply district in this part of the State to include the cities of Fall River, New Bedford and Taunton, and such of the towns in the vicinity of these cities or in the vicinity of the Lakeville Ponds as may desire to join. This would involve the creation of a commission composed of members clothed with sufficient authority for the purpose under a legislative act following the general method adopted at the time of the creation of the Metropolitan Water District. Each municipality would still maintain under such a plan its own individual water system, as is the case in the Metropolitan Water District. To the commission would be left all questions relating to securing, protecting and developing to their full extent the water supplies in these ponds. The commission should be authorized to acquire lands within the watersheds and construct and maintain necessary dams and other appurtenances, together with all drainage works needed for the improvement and maintenance of the water in the ponds, in the best condition. They should also have control of the enforcement of rules for the sanitary protection of the water and the policing of the watersheds and ponds and the location of al intakes or connections with the ponds."

As part of this report, legislation was recommended and given long and serious consideration by the legislative Water Supply Committee and

the various cities and towns interested in the matter. Fall River joined in urging this measure as first presented, which contemplated the utilization of the entire group of ponds under the control of such a Water District.

At the present time New Bedford utilizes two of the ponds, viz. Great and Little Quittacas Ponds, for its water supply, including a drainage area of about 13 sq. mi. out of a total of some 48 sq. mi. for the entire group of ponds. Taunton, with a pumping station on Assawompsett Pond, uses a relatively small amount of the yield of that pond.

In the course of the hearings before the Water Supply Committee it developed that New Bedford did not wish to have the portion of these ponds, viz. Great and Little Quittacas, now controlled by it included in the Water District, and as this involved a much less satisfactory use of the pond system as a whole, as well as materially greater cost to the city of Fall River, the latter has opposed any such sub-division of this pond system.

Essentials regarding area, capacity and the probable safe yield of the Lakeville Pond system appear in the following table taken from the report by the writer on Additional Water Supply for Fall River, dated July 14, 1917: —

PROBABLE SAFE YIELD OF LAKEVILLE PONDS

Pond or Drainage Area.	Drainage Area Sq. Mi.	Per Cent. Water and Swamp Area.	Storage Capacity Assumed. Mil. Gals.		Safe Yield.	
			Total.	Per Sq. Mi.	Mil. Gals. Per Day Per Sq. Mi.	Total Mil. Gals. Per Day.
Long Pond raised 2 ft. El. 49–54	22.3	13.5	3 100	140	0.63	14.0
Assawompsett Pond ..	12.8	33.5	4 300	335	0.68	8.7
Quittacas Ponds	12.8	17.5	3 200	250	0.74	9.5
Snipatuit Pond	6.8	17.5	1 250	184	0.68	4.6
Total, *not* including Snipatuit	47.9	23	10 600	223	0.68	32.2
Total, including Snipatuit	54.7	23	11 850	250	0.68	36.8

In the foregoing table draft to a depth of 5 ft. was assumed for all but the Quittacas Ponds, which were assumed at 7 ft. An additional 2 ft. on top of Long Pond (or a draft from El. 49 to El. 56) would add about 1 500 million gallons of storage capacity, making a total safe yield of about 35 million gallons per day, based upon the yield of the Sudbury River 1879-84, which stream shows about the same yield as the Lakeville Ponds, according to measurements of flow from the latter made by the late Freeman C. Coffin, from December, 1894 to November, 1897.

The report by the State Department of Health of January, 1922 (p. 228) gives the total storage capacity at about 21.3 billion gallons, which evidently corresponds to a much greater draft upon all the ponds. The conclusion in regard to safe yield of 42 million gallons in this report appears reasonable, however, in view of storage possibilities.

Reference to the foregoing table indicates that nearly half of the yield of this pond system comes from Long Pond and its drainage area. The waters of Long Pond and its tributary streams are, however, relatively high in color and must be stored for a very considerable period of time in the lake system to be desirable for use. The manner in which New Bedford has developed its supply is indicative of the best use of this pond system, and the fuller development of the system by cities lying southerly, like New Bedford and Fall River, would naturally be by taking water from Little Quittacas Pond, just as New Bedford has done, thus providing that the highly colored waters of Long Pond before use must travel many miles around and through Assawompsett Pond, thus lowering the color content to a small amount.

The manner is which Fall River has planned to utilize the Lakeville Ponds as an additional supply is shown on the accompanying map, (Fig. 8), and includes a pumping station on Little Quittacas Pond, with pipe line leading to a large distribution reservoir on Copecut Hill, a couple of miles easterly from North Watuppa Pond. Further details of this proposed reservoir will be given later. As a part of the additional water supply system, it will provide a means for the use of the Lakeville Ponds water by one pumping, as the new reservoir will be somewhat higher in level than the present tanks or standpipes in the city. Any method of using the waters of Long Pond directly by pumping them into North Watuppa Pond and storing them there to lower the color content would involve pumping water over the divide in the general vicinity of Mill Brook, a total of about 150 ft. and then a repumping later at the main pumping station on North Watuppa Pond.

It would be possible for Fall River to locate its pumping station on Assawompsett Pond and obtain there water of suitable color content. It is obvious, however, that this would involve some three miles additional length of pipe line, at greater first cost, as well as increased cost of maintenance and pumping, without any corresponding benefit to any one. Furthermore, to get the best results from storage operation, of increasing importance as the water demands of this district grow, these ponds should be dealt with as a unit.

New Bedford has shown great foresight in planning its water supply from the Quittacas Ponds and should be fully compensated for what she has already done in dedicating a considerable part of this pond system to municipal water supply use. The consumption of water in New Bedford is rapidly increasing, however, being now in the vicinity of 10 million gallons per day, or not far from the safe yield of the two Quittacas Ponds.

The city must therefore soon take additional water from the pond system and is therefore vitally interested in the adequate control of all these ponds under a water district.

Legislation is still pending upon this important matter and it is the

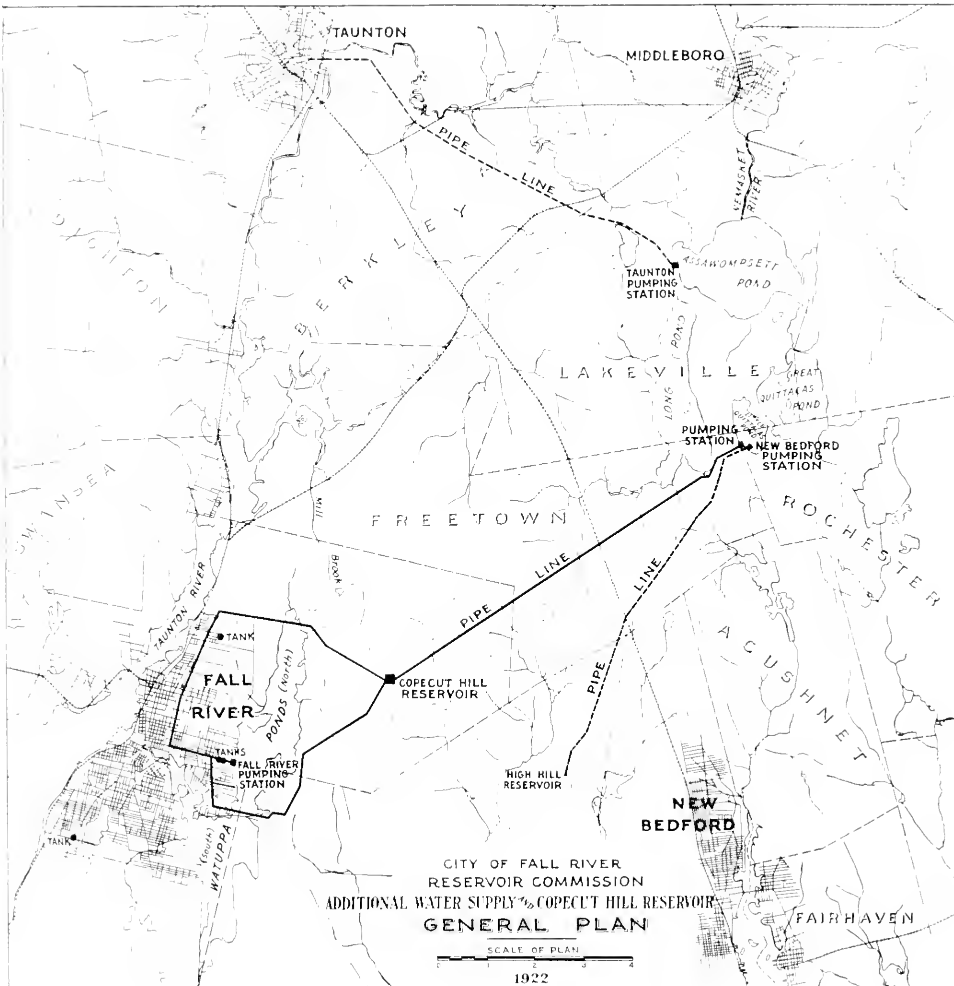


FIG. 8.

hope of Fall River that, if possible, the full and comprehensive use of this pond system may be reached.

Legislation was obtained during the winter of 1921–22 covering the matter of Copecut Hill Reservoir, as well as necessary pipe line connection with the city from this reservoir, and plans are now being prepared for this work. At the present time test pits are being dug at different sites on the hill and information obtained to use as a guide in determining the best

method of construction of a reservoir and its probable cost. A large reservoir holding from a week to ten day's supply of water is contemplated at an elevation somewhat in excess of the level of the present tanks or standpipes, viz. El. 305. As far as the investigations have proceeded it appears that a reservoir can be obtained at a level as high as El. 340, if desired, and that this will probably be of earth embankment type, constructed partly in excavation, partly in fill, with concrete lining.

The construction of an adequate distribution reservoir has been under consideration for many years, as the combined capacity of the four present tanks is only about five million gallons or less than a day's average use of water. There is no available site for such a reservoir within city limits — the highest points reaching only about to El. 260. Copecut Hill is at a considerable distance from the city and will hence require a large expense for connecting pipe mains. On the other hand, certain districts of the city, at about El. 200 or above, where pressures at present are low and unsatisfactory, will be materially and directly benefited by these pipe lines. Furthermore, a reservoir on Copecut Hill fits admirably into the proposed Lakeville Ponds additional supply, by saving an extra pumping of water as already noted.

The cost of the Lakeville additional supply and the Copecut Hill Reservoir and its connections will probably be in the vicinity of $2 000 000, of which approximately $1 500 000 represents the cost of the reservoir and its connections, etc., and the remaining $500 000 the cost of pumping station, pipe line, etc., from Little Quittacas Pond. (If the latter pond is not available, the cost will be materially increased.) Added to this cost will be the proportion which Fall River must pay for the joint use of the Lakeville Ponds with other municipalities, which will add a considerable further amount to the cost of this project.

It is likely that the complete program of additional water supply for Fall River may involve an expenditure of as much as $2 500 000. While this at first glance appears to be a large amount, when compared with the cost of such projects in other cities it is seen to be reasonable. It is, in fact, just about what the New Bedford supply from Quittacas Ponds has cost, including the High Hill Reservoir and its connections with the city. The city of Providence (approximately double the size of Fall River) is spending in excess of $10 000 000 for its new water supply, the contract for the main dam alone at the new Scituate Reservoir totalling about $3 500 000.

The cities of Fall River, New Bedford and Taunton and neighboring towns are indeed fortunate in being located near such a large supply of good water as is afforded by the Lakeville Ponds system, which will provide for their water supply needs for many years, if properly conserved and controlled. Contrast with this the situation with the cities of Lawrence, Haverhill, etc., in the Merrimac Valley, now being studied by the State Department of Health, where additional water supply needs are already

urgent and the difficulties of meeting these adequately are very considerable.

In carrying out the work described at Fall River up to 1917 Mr. Arthur L. Shaw was Resident Engineer, to whom much credit is due for the results achieved — particularly in the construction of the intercepting drain. The success of this latter piece of work was also largely due to excellent construction on the part of the contractor, the Hanscom Construction Co. of Boston, who, at some loss, executed this work in a first-class manner. Since 1917 Mr. John Brown has been Resident Engineer in direct charge of both the water supply and river improvement work. The writer has acted as Consulting Engineer for the Watuppa Reservoir Commission since 1914 and for the Quequechan River Improvement since 1916.

Fall River Intercepting Drain — Cost Data 1915–16.

Cost per Linear Feet for Different Sections of Diameter.

6 ft. open section (1470 lin. ft.)						
Concrete	0.427	cu. yd.	@	$9.50	=	$4.06
Reinforced steel	40.64	lb.	@	0.023	=	0.95
Excavation	2.7	cu. yd.	@	0.85	=	2.30
Total						$7.31
8 ft. open section (2600 lin. ft.)						
Concrete	0.458	cu. yd.	@	$9.50	=	$4.35
Reinforced steel	55.31	lb.	@	0.023	=	1.29
Excavation	4.1	cu. yd.	@	0.85	=	3.49
Total						$9.13
10 ft. open section (5608 lin. ft.)						
Concrete	0.505	cu. yd.	@	$9.50	=	$4.80
Reinforced steel	59.50	lb.	@	0.023	=	1.39
Excavation	5.4	cu. yd.	@	0.85	=	4.60
Total						$10.79
6 ft. covered section (154 lin. ft.)						
Concrete	0.536	cu. yd.	@	$9.50	=	$5.10
Reinforced steel	72.46	lb.	@	0.023	=	1.70
Excavation	1.5	cu. yd.	@	0.85	=	1.27
Total						$8.07
10 ft. covered section (2312 lin. ft.)						
Concrete	1.00	cu. yd.	@	$9.50	=	$9.50
Reinforced steel	145.41	lb.	@	0.023	=	3.41
Excavation	3.7	cu. yd.	@	0.85	=	3.14
Total						$16.05

In the foregoing tabulation costs as given are approximate actual costs, not contract prices. Unit costs are, however, for the work as a whole and are not available in segregated form for the various individual sections of drain. Rock excavation is *not* included.

The *unit cost of concrete* (7 618 cu. yd.) was made up as follows:

Labor, teaming, insurance, etc.	$1.27	
Machinery, power and general	0.93	
Lumber for forms, etc.	0.25	
Sand, $0.66 and Stone, $1.39	2 05	
Cement	2.00	
TOTAL	$9.50	per cu. yd.

The cost of forms (in place and removed) — made of wood, for a total area of about 280,000 sq. ft. was about eight cents per sq. foot.

The *unit cost of earth excavation* (58,500 cu. yd.), including refill, was as follows: —

Clearing and burning	$0 02	
Stripping and storing loam	0.17	
Excavating other earth	0.47	
Backfill, etc.	0.16	
Machinery, pumps and miscellaneous	0.03	
TOTAL	$0.85	per cu. yd.

Rock excavation, not included in the costs previously given for different sections of the drain, totalled about 6700 cu. yd. for the total length of concrete section of about 12,144 ft., or just about 10 per cent. of the total excavation. Of this rock practically one-third was boulders of one-half cu. yd. or more, the remainder ledge.

The cost of rock excavation was about $19 500, which averages $1.60 per linear foot of drain and about $2.90 per cu. yd.

Base costs for labor and material were:

Ordinary labor	$1.80	per day of 9 hours
Single teams and driver	3.75	" " " 9 "
Double teams and driver	5.50	" " " 9 "

Cement	$1 20	per bbl.
Sand	1 50	" cu. yd.
Crushed stone	1 58	" cu. yd.
Dynamite	0.20	" lb.
Reinforced steel	0 023	" lb.

Discussion.

Mr. Francis T. Kemble.* I would like to inquire what they are doing at the present time in connection with taking care of drainage from those cottages which are shown along the banks in two instances, I think.

Mr. Goodnough. All of these watersheds are under the control of the local authorities. They are protected by rules and regulations which are enforced by the Water Boards in each case. They are cared for very carefully as far as my knowledge goes, in both watersheds. There is nothing around the New Bedford supply to do harm in any case, and in Taunton I think the rules are carried out very strictly.

Mr. Kemble. Are there any cesspools?

Mr. Goodnough. The regulations call for no cesspools within 50 ft. of the water, or within 50 ft. of any water course.

Mr. Robert S. Weston.† Do those regulations apply to Long Pond as well as to Assawompsett?

Mr. Goodnough. No, they do not. We can't even stop bathing in Long Pond. I think that it depends on the judge before whom bathers are taken.

Mr. Weston. What are the relative elevations of High Hill Reservoir and the proposed Copecut Reservoir?

Mr. Goodnough. Copecut Reservoir is a great deal higher than High Hill.

Mr. Caleb M. Saville.‡ I have been very much interested in both of these descriptions of water supplies, particularly in the data which Mr. Goodnough has so well brought forward with regard to the growth of the population. It seems to me that this is a matter of considerable importance because of its bearing in making up estimates for additional water supplies and for financing them, the relation between the growth of European cities and those in America; whether they are strictly comparable. What Mr. Goodnough has said of the English cities is most interesting and instructive. Of course we must base our estimates of the future growth of population on information of that kind. In America there are comparatively few cities which can be compared after they have reached populations of 150 000 to 200 000 or more because of local environment which inequally affects the growth. Also conditions seem to me vastly different in American cities from those in English cities. England, on account of racial characteristics, perhaps, and again on account of geographical conditions, is in a somewhat different position as to its city growth. You can't get out of England. England is a comparatively small place. The coal mines, which are the basis of the English industry, are located not far from the big centers. The Englishman always moves

* Secretary New Rochelle, N. Y., Water Co.

† Consulting Engineer, Boston, Mass.

‡ Chief Engineer, Board of Water Commissioners, Hartford, Conn.

slowly. In America we move more rapidly and so it seems we can not make direct comparison.

This was particularly brought to my attention in considering what the effect will be on some of our Connecticut cities that have now reached a population of perhaps 150 000 or 175 000. Consider the effect of the big movements that are on foot, perhaps this super-power proposition that is now rather agitating us, of bringing the larger industry to the coal mines; or developing power at the coal mines, if you please.

It is desirable, perhaps, to get our industries nearer the source, to get cheaper labor and less transportation difficulties, but large movements of this kind seem bound to affect local growth. That is particularly pertinent, at this time I think, on account of the sale or the transfer of the stock recently, of the American Brass Company, which has large industries in Torrington, Waterbury and Ansonia, to the Anaconda Copper Company. Those industries are practically the life of those Connecticut cities I have mentioned. There is a thought, and it is rather a serious one, that in time the bulk of the product now made by the American Brass Company in those towns will be transferred to the nearer copper fields in Butte for sheet copper and plain bulky materials. What bearing such a movement will have on the growth of those particular Connecticut cities is problematical.

Mr. Theodore L. Bristol.* I do not think anyone knows what the result will be in the Naugatuck Valley. When the Anaconda Company bought the American Brass Company they were very careful to state that it would make no difference with the organization, that they intended to keep the mills running and the same people. I think it is some question how this will work out. Probably there will be changes.

I was in the operating manager's office in Ansonia the other day and there was a call for wire drawing dies. It seems the Anaconda Company had placed an order for wire drawing dies to be shipped to Butte and were not getting them fast enough, and they wanted to know if they could borrow some from Ansonia. The dies were immediately sent them from surplus stock. That shows that they are probably transferring a lot of wire drawing to Butte, and I presume they will take care of their western territory at Butte and will eventually establish sheet mills there. The copper business is pretty good now; they are trying to work twenty-four hours a day in Ansonia. It started with the wire mill which has been working twenty-four hours for several months. They have built a new mill in Ansonia, quite a large wire drawing mill. Probably that will not be abandoned. But it all depends upon where the demand comes from.

Of course in all these localities there have been other businesses that are called cutting up shops. They are the people who manufacture the copper into other articles. That will tend to keep the business in this locality which is in the locality of the present brass and copper cutting up shops.

---

* President Ansonia Conn., Water Co.

Perhaps to show how things may move, I will say that there is another large industry in Ansonia, the Farral Foundry and Machine Company, which has bought quite a large plant in Buffalo because it saved considerable in freight on coal and iron. I think they did that principally for manufacturing rubber mill and wheat rolls to be shipped to Ohio and the West. But it has made no noticeable difference with Ansonia.

President Barbour. I was interested in what Mayor Remington told me regarding some statement in a paper which he had recently unearthed about the removal of the textile industry to the South some fifty years ago.

Mayor W. H. B. Remington. I would be very glad, Mr. President, to say what I said to you about that particular matter.

In 1855 my father was an operative in the Wamsutta Mills here. At that time he purchased a little book which was called "American Cotton," containing more or less details about the cotton business. During the last year I came across that book, and in it found an almost exact reproduction of the argument which has been made within a short time about the removal of the cotton business to the South. That was over fifty years ago, and the cotton mills are still in this section of New England. Of course they have many mills in the South. That led me to think that possibly there might be more or less bugaboo about that suggestion.

TARS, NEW AND OLD.

BY S. R. CHURCH.

[*December, 1922.*]

Introductory.

Coal tar is so valuable as the source of many useful materials in chemistry and in engineering, it is of such scientific and commercial importance, that one is compelled to express surprise as well as regret that there is no comprehensive reference book on the subject. I say this with due regard to Lunge's extensive work on coal tar and ammonia, long considered authoritative. In recent editions of this once valuable work no real effort has been made to bring the facts down to date and it is especially deficient as regards American practice. The book contains much wheat and a great deal of chaff and the reader is compelled to sift for himself.

Warnes hand book on coal tar distillation is concise and describes English tar distilling practice quite well, but the author has made no attempt to cover the entire subject and his book is of value to the tar distiller but not to the users of tar products. The same can be said of Kreamer and Spilker's chapter on coal tar in Muspratt's Chemistry (German), and a fairly exhaustive treatise in French by Berthelot, printed in *Revue de Metallurgie.*

In fact the engineer or chemist who desires to use tar products finds the literature pretty barren and indeed many of the scanty references available are inaccurate. For instance in the very useful Lefax tables, the specific gravity of " tar " is given at 1.015. Of course all tar is not coal tar and there may be some variety of wood tar having that specific gravity, but it is to be feared that some will apply this value to coal tar.

Even such a dignified authority as the Encyclopedia Britannica is guilty of this, " The heavier tars contain less benzol than the lighter tars and more fixed carbon, which remains behind when the tars are exhausted of benzol and is a decidedly objectionable constituent." It is no wonder that engineers who have had little actual contact with coal tar find it very difficult to define their requirements when in need of tar products, or that some of the specifications met with are drawn without a real understanding of materials and purposes.

The whole matter of writing specifications for the cruder forms of tar products (meaning creosote oil, road binders, pipe coatings as distinguished from refined products such as phenol or naphthalene) has been surrounded by more than ordinary difficulty. Tars are by-products and

their physical character and composition are determined by conditions existing in the gas retort or coke oven, conditions over which the tar distiller has no control.

The tar distiller has had to take tars as produced, and determine as best he could, by field experience and laboratory research, how to convert them into uniform products suitable for the purpose intended. Looking at the subject from a modern chemical engineering standpoint, it must be admitted that rule of thumb methods prevailed in the tar refinery until about ten years ago. During the past ten years much progress has been made and not only have good workable specifications been developed for the principal tar products; but many improvements and economies have been worked out in the distilling and other refining processes, based on a growing knowledge of the physical constants and composition of the materials dealt with. Time does not permit going into this phase of the subject but it may be mentioned that our researches have included determining the specific heat of tar distillates and residues, the vapor density and molecular weights, latent heat of vaporization, etc. Obviously all of these facts are needed in correctly designing distilling equipment but they are absolutely unavailable in the literature.

The object of this paper is to endeavor to show by some typical and comparative analyses the general range of American tars including coal tars from gas works and coke ovens and water gas tars from petroleum gas oil. These are properly considered together as they comprise the tars dealt with by American tar distillers. We hear of wood tars, blast furnace tars, lignite tars, producer tars, etc., but these are either foreign to this country or to American tar distilling practice.

The best available statistics (Mineral Resources of the U. S. 1920 and 1915) give the tar production as —

	1920		1915
Tar Gallons.	Production.	Sales.	Production.
Coke Oven	360 000 000	174 000 000	140 000 000
Coal Gas	51 000 000	46 000 000	45 000 000
Water Gas	114 000 000	58 000 000	80 000 000

The later figures are no doubt more nearly accurate but the growth in production is apparent, as well as the fact that the increase is largely in tar produced on by-product coke ovens. However, the tar available to the distillers has not changed so largely as to its source, as the total figures indicate, due to the rather wide adoption of tar burning on the part of many of the by-product oven owners.

Methods of Testing Tars.

Before considering the characteristics of different types of American tars it will be useful to illustrate and briefly describe some of the laboratory tests ordinarily made on crude and refined tars and by means of which we identify and classify the crudes and control the consistency of the refined tars and soft pitches.

DISTILLATION TEST.

The apparatus illustrated in Fig. 1 is used for testing crude tar for water and also for distilling tar to pitch and determining the per cent. oil yield. The oil and pitch obtained can be further examined if desired.

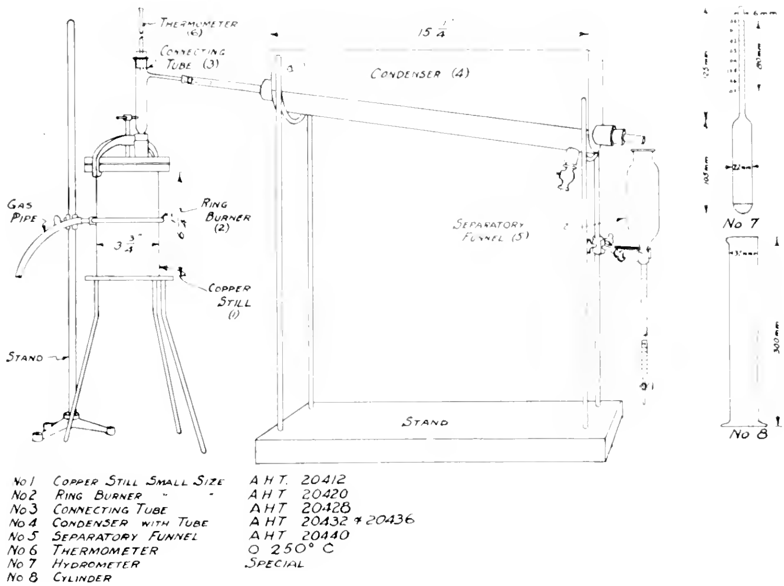


Fig. I — Apparatus for Distillation.

When water only is to be determined

Crude Tar Tests — Water.

Apparatus. Copper still, 6 in. by $3\frac{1}{2}$ in. Ring burner to fit still. Connecting tube. Condenser trough. Condenser tube. Separatory funnel. Thermometer, 0°-250° C. See Fig. I.

Method. Fifty cc. of coal tar naphtha or light oil shall be measured in a 250 cc. graduated cylinder, 200 cc. of the tar to be tested shall be added. The contents shall be transferred to the copper still, the cylinder shall be washed with 100-150 cc. more of naphtha, and the washings added to the contents of the still. The lid and clamp shall be attached, using a paper gasket, and the apparatus set up as shown in Fig. II. The condenser trough shall be filled with water. Heat shall be applied by means of the ring burner, and distillation continued until the vapor temperature has reached 205° C. (401° F.). The distillate shall be collected in the separatory funnel, in which 15 to 20 cc. of benzol have been previously placed. This effects a clean separation of the water and oil. The reading shall be made after twirling the funnel and allowing to settle for a few minutes. The percentage shall be figured by volume.

Precautions. When fresh supplies of naphtha or light oil are obtained, they shall be tested to determine freedom from water.

Accuracy. One-tenth of 1 per cent.

Note. For works control an iron still of the same size and shape as the copper still specified above may be used. Some laboratories omit

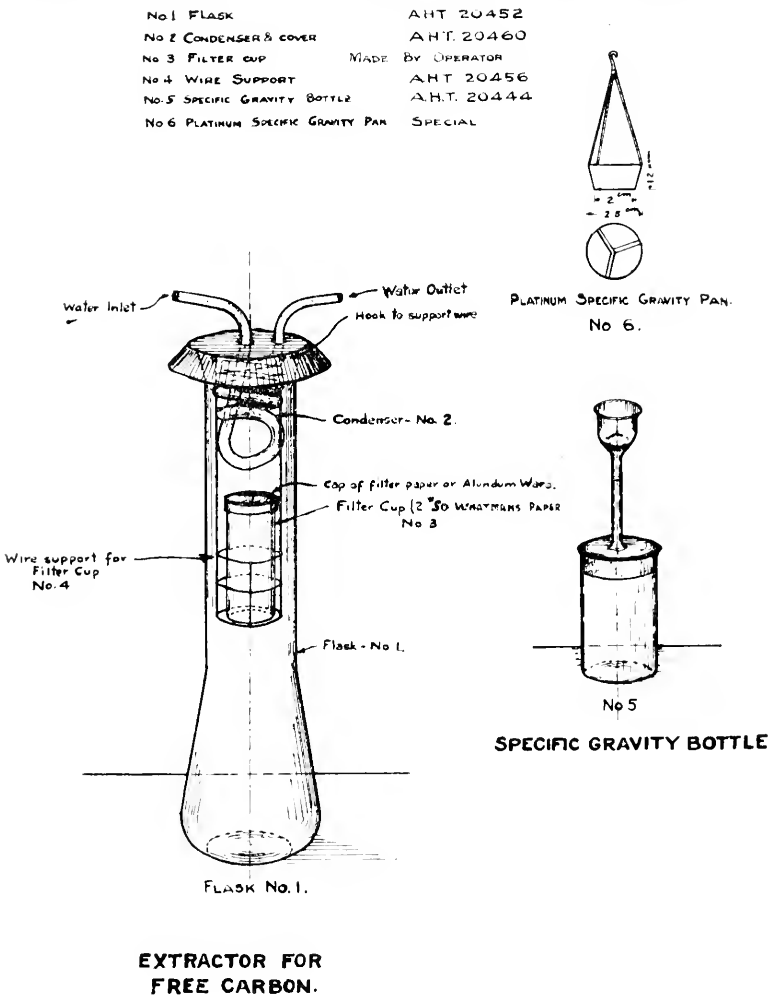


FIG. II.

the use of the thermometer and judge when the water is off by the appearance of the distillate. These variations must never be applied where check test is required or in case of dispute.

Dehydration (Preparation of Dry Tar) — Apparatus.

Method. About three hundred to four hundred cc. of tar shall be placed in the copper still without the addition of naphtha. The apparatus

shall be set up as in Fig. I, except that an ungraduated separatory funnel may replace the special graduated one. The distillation shall be carried on cautiously at first to prevent foaming and continued until the vapor temperature reaches 170° C. (338° F.). Any oil which has distilled over shall be separated from the water (warming sufficiently, if crystals are present, to insure their solution). This separated oil shall be thoroughly mixed back into the residual tar in the still, after the latter has cooled to a moderate temperature. The dehydrated tar shall be then transferred to a suitable container.

Note. A temperature of 170° is used because this is sufficiently high to expel all water from the still. In test I a higher temperature is used to insure flushing out the condenser tube.

When oil yield to a given temperature, or to a certain melting point of pitch, is desired, the addition of naphtha is of course omitted.

The stills can be had in a larger size fitted with a convenient draw-off cock for sampling the pitch and emptying the contents of the still.

EXTRACTION WITH BENZOL.

Crude tar, if it contains not more than about 5 per cent. of water may be tested but for accurate results the tar should first be dehydrated in the distillation apparatus heretofore described.

The test as described is also applicable to refined tars and pitches.

Insoluble in Benzol (Free Carbon).

Apparatus. Extraction flask. Condenser and cover, wire support. See Fig. II. Extraction thimble (prepared by operator).* Cap of filter paper or alundum. The latter are 30 mm. inside diameter by 14 mm. high. Balance: an ordinary analytical balance accurate to 0.0005 g. Steam bath, water bath, or electric hot plate. Beakers, 100 cc. Carbon filter tubes, 37 mm. size. Weighing bottle, 32 mm. by 70 mm. Camel's hair brush, 14 mm.

Method. Tar dried as described under Test I shall be used. After drying, it shall be passed hot through a 30-mesh sieve to remove foreign substances. The amount of tar to be taken for test depends on the content of insoluble material and shall be:

Less than 5 per cent., 10g.
5 per cent. to 20 per cent., 5 g.
Above 20 per cent., 3g.

If the content of insoluble material cannot be approximated, the larger amount shall be taken. The amount shall be weighed into a 100 cc. beaker

---

*These shall be made of Whatman No. 50 filter paper. To make a cup, two 15 cm. circles shall be taken and one cut down to a diameter of 11 cm. A round stick about 1 in. in diameter shall be used as a form. The stick shall be placed in the center of the circles of filter paper, the smaller inside, and the papers folded symmetrically around the stick to form a cup about 2½ in. long. A little practice enables the operator to make these evenly and quickly. After being made they shall be soaked in benzol to remove grease due to handling, drained, dried in a steam oven at 97° to 100° C., cooled in a desiccator and kept there until used.

and digested with pure toluol at 90° to 100° C. for a period of *not over thirty minutes.* The solution shall be stirred to insure complete digestion. A filter cup prepared as described shall be weighed in a weighing bottle and placed in a filter tube supported over a beaker or flask. The thimble shall be wet with toluol and the toluol-tar mixture decanted through the filter. The beaker shall be washed with toluol until clean, using the camel's hair brush as a policeman to detach solid particles adhering to the beaker. All washings shall be passed through the filter cup. The filter cup shall then be given a washing with pure benzol and allowed to drain. The cap shall then be placed on the cup and the whole placed in the extraction apparatus and extracted with pure benzol until the descending benzol is completely colorless. The cup shall then be removed, the cap taken off, and the cup dried at 97° to 100° C. After drying, it shall be allowed to cool in a desiccator and weighed in the weighing bottle. The increase in weight represents matter insoluble in benzol.

Precaution. If the first filtrate shows evidence of insoluble matter, it should be refiltered. The 30-min. period allowed for digestion must not be exceeded.

Accuracy. Five per cent. of insoluble matter present. In other words, with 20 per cent. of "free carbon" present, a 1 per cent. accuracy may be expected.

MELTING POINT OF PITCH.

This method is universally used by producers and consumers of tar pitches to determine its consistency and is applicable to the range of pitches from those which will hardly retain form at normal temperature (about one hundred degrees F. melting point) to those which can hardly be "chewed," or indented with the finger nail (about one hundred seventy degrees F. melting point.)

Test D6 — Water Melting Point.

Apparatus. See Fig. III.

Pitch mould. Hook made of No. 12 B. and S. gage copper wire (diam. 0.0808 in.). Beaker, 600 cc., Griffin's low form.

Thermometer: The thermometer shall conform to the following specifications:

Total length	370 to 400 mm.
Diameter	6.5 to 7.5 mm.
Bulb length	Not over 14 mm.
Bulb diameter	4.5 to 5.5 mm.

The scale shall start not less than 75 mm. above the bottom of the bulb and extend over a distance of 240 to 270 mm. The graduations shall be from 0° to 80° C. in $^1/_5$° C. and shall be clear cut and distinct.

The thermometer shall be correct to 0.25° C. as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the Bureau of Standards.

The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and so annealed as not to change its readings under conditions of use.

Methods. *(a) Pitches having melting points between 43° C. and 77° C., (110° to 170°.).* A clean shaped half-inch cube of pitch shall be formed

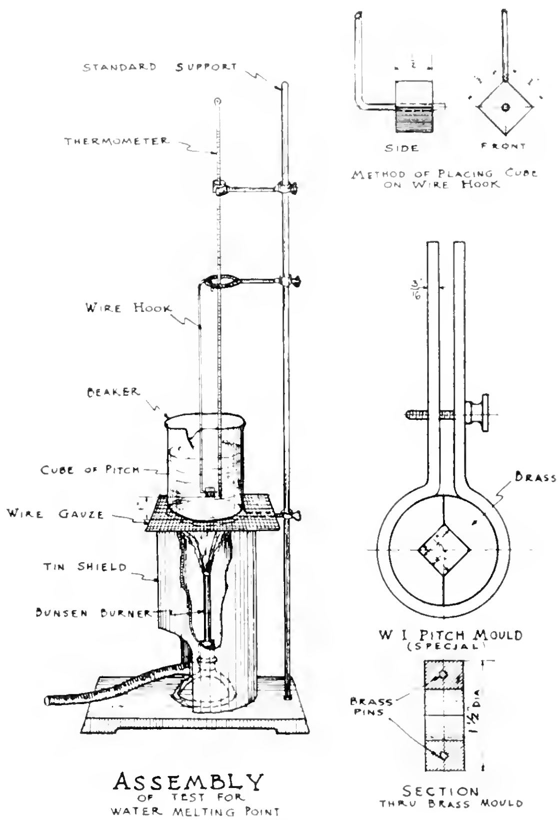


FIG. III.

in the mould and placed on the hook or wire (see Fig. III for detail of method of placing the cube on the wire). The apparatus shall be assembled as shown in Fig. III, placing 100 cc. of freshly-boiled distilled water at 15.5° C. in the beaker.

The thermometer shall be placed so that the bottom of the bulb is level with the bottom of the cube of pitch and shall be immediately contiguous to, but not touching, the cube.

The pitch cube shall be suspended so that its bottom is 1 in. above the bottom of the beaker and allowed to remain in the water at 15.5° C. for 5 min. before starting the test. Heat shall then be applied in such a manner that the temperature of the water is raised 5° C. (9° F.) each

minute. The temperature recorded by the thermometer at the instant the pitch touches the bottom of the beaker shall be reported as the melting point.

(*b*) *Pitches having melting points below 43° C. (100° F.).* These shall be tested exactly as under *a*, except that the water at the start shall be 4° C. (40° F.) and the cube shall be allowed to remain 5 min. at this temperature before starting to apply the heat.

Precautions. The use of boiled distilled water is essential, as otherwise air bubbles may form on the cube and retard its sinking. The rate of rise must be uniform and not averaged over the period of the test. All tests where the rise is not uniform shall be rejected. A variation of not more than ±0.5° C. for any minute period after the first three is the maximum allowable.

Accuracy. ±1° F.

Notes. Pitches of the *a* range of consistency can ordinarily be molded at room temperature, but, if necessary, cold or hot water can be used to harden or soften them. Pitches of the *b* range can be conveniently formed in water of about 4° C. (40° F.).

A sheet of paper placed on the bottom of the 600 cc. beaker and conveniently weighted will prevent the pitch from sticking to the beaker when it drops off, thereby saving considerable time and trouble in cleaning.

This method shall not be used on pitches above 77° C. (170° F.), water-melting point.

CONSISTENCY.

(Schutte penetrometer).

This is adaptive to refined tars that are too heavy for the ordinary orifice viscosimeter test except at high temperatures, and too soft to be classed as pitch.

Consistency (Schutte).

Apparatus. Schutte penetrometer (see Fig. IV). Stop watch.

Method. The collar shall be filled by placing it upon a flat tin roofing disk which has been coated with a thin film of vaseline and pouring an excess of material into the collar. After cooling and contraction the excess material shall be cut off level with the upper edge of the plug by means of a heated knife blade. The collar shall be then immersed in water of the required temperature and left at that temperature for 15 min. The collar with roofing disk attached shall be screwed into the tube while the tube is in position. The water bath shall just cover the shoulder of the tube. The tube shall be filled with water of the required temperature and the roofing disk removed by slipping it sideways. The time (measured by a stop watch) from the slipping off of the disk to the sudden drop of the disk to the sudden drop of the water in the tube, shall be noted and reported in seconds.

Precautions. Take extreme care to keep the water bath within 0.5° F. of the required temperature.

(Float Test).

This applies to the same class of material as mentioned under (4). Recently, Committee D4, A.S.T.M. have issued new detailed specifica-

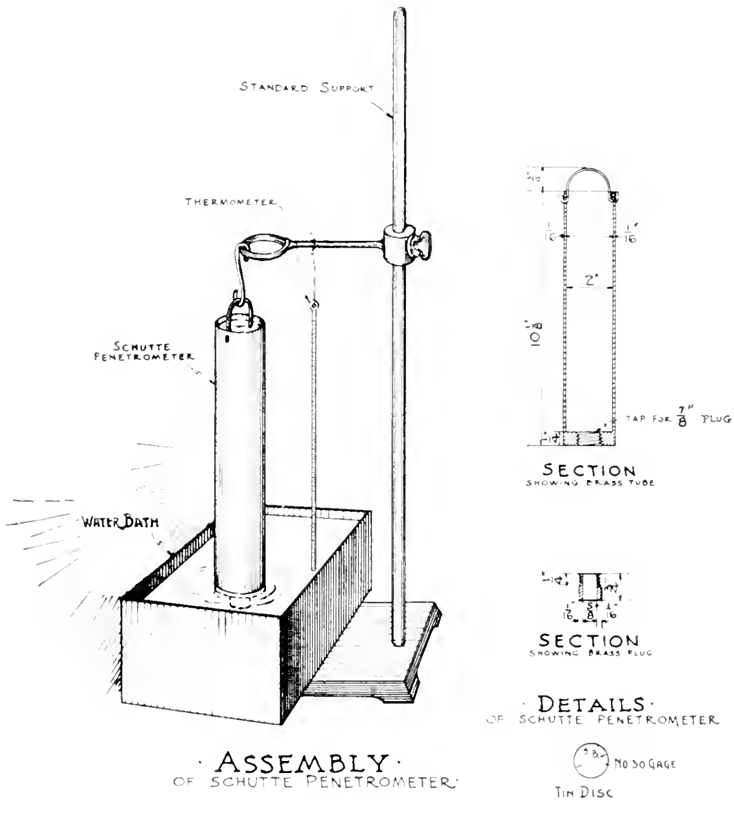


FIG. IV.

tions for the float instrument and these differ somewhat from the dimensions illustrated. The A.S.T.M. specifications should be adhered to in order to obtain consistent results.

CONSISTENCY (Float)*

Apparatus. Float tester (see Fig. V). Brass plate, 5 x 8 cm. Stop watch.

Method. The brass collar shall be placed with the small end down on the brass plate which should be previously amalgamated with mercury by rubbing it first with a dilute solution of a mercury salt and then with

* Adapted from Bulletin 314, Office of Public Roads.

metallic mercury. Sufficient of the material to be tested shall then be melted in a suitable container, care being taken to prevent loss by volatilization or formation of air bubbles. The material shall then be poured into the collar in a thin stream until slightly more than level with the top. The surplus shall be removed, after cooling to room temperature, by means

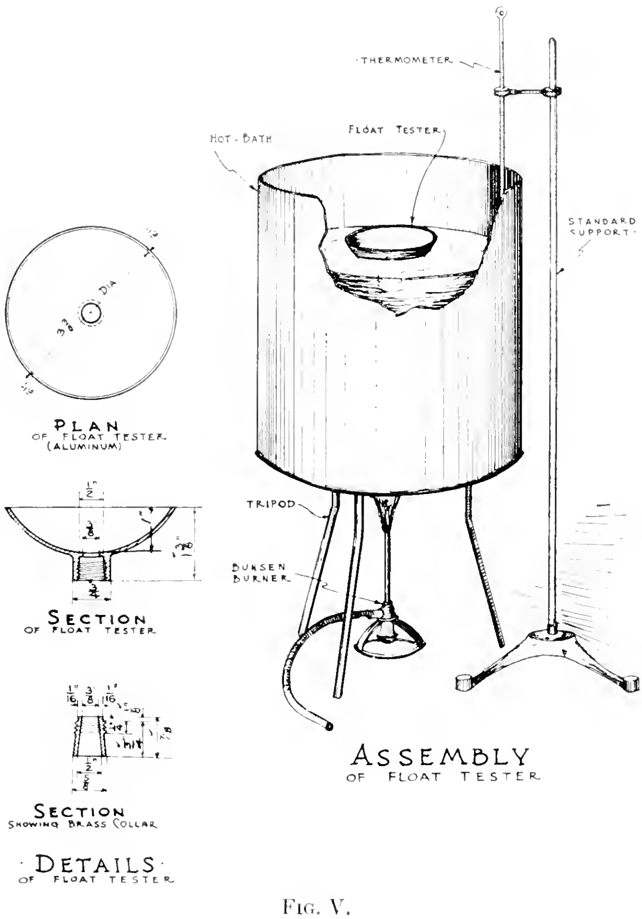


FIG. V.

of a steel spatula, the blade of which has been slightly heated. The collar with plate attached shall then be placed in water at 5° C. and allowed to remain at that temperature for at least 15 minutes. A suitable water bath shall be filled $\frac{3}{4}$ full of water, placed over a burner and brought to the temperature at which it is desired to make the test. This temperature shall not be allowed to vary during the test more than 0.5° C. from the required point. The brass plate shall be removed from the collar and the latter with contents shall be screwed into the aluminum float, which shall then be immediately floated on the carefully regulated warm bath. As the

plug of bituminous material becomes warm and fluid, it is gradually forced upward and out of the collar until the entrance of water causes the collar to sink. Unless otherwise specified, the time in seconds (noted by a stop watch) from placing the float in water to the *time the water breaks through the material* shall be reported as the consistency of the material.

Precautions. No test should be recorded if water finds its way into the float through the thread of the plug. This can be avoided by thoroughly coating the thread with grease or vaseline.

Notes. In certain specifications it is required to take the time from placing the float in water until the float sinks. This may make a difference of 5 to 10 seconds in the result. Tests are ordinarily made at 50° C. At 100° C. the test is not at all sensitive for distilled tars.

Characteristic Properties of Typical Tars.

Table I gives analyses of three gas works tars, three by-product coke oven tars and two water gas tars. Horizontal retort tars as shown to be highest in specific gravity, insoluble matter and viscosity — while vertical retort tar is lower in those values than coke oven tars. Water gas tars fall in a still lower range.

TABLE I.

Analysis of Typical Tars.

Origin.	Gas Retort.			Coke Oven.			Water Gas.	
	Horizontal.	Horizontal.	Vertical.					
Specific gravity crude	......	1.198	1.180	1.179	1.172	1.176	.....	1.110
Water, per cent	......	5.3	1.2	1.6	4.6	2.8	.....	4.9
Dry Tar.								
Specific gravity 15.5° C.	1.266	1.222	1.166	1.181	1.188	1.193	1.083	1.121
Insoluble in benzol	28.9	21.1	6.0	6.8	9.2	4.7	0.1	2.6
Ash, per cent	......	0.2	......	0.03	0.01	0.2	0.1	0.1
Viscosity 50°-C sec.	......	.....	128	217	107	.....	80	.....
Viscosity 115°-C sec.	300+	67	30	34	42	38	25	42
Oil to soft pitch	13.2	21.0	26.5	24.3	29.6	30.7	43	.....

Table II shows the general range of each class of tars, i.e. minimum and maximum limits of the different properties. These will be later referred to in discussing their relation to the application of the various tars in pipe coating.

TABLE II.

PROPERTY OF COAL TARS.

Properties	Gas-Works Coal Tar. Horizontal Retorts.	Inclined Retorts.	Vertical Retorts.	Coke Oven Tars.
Specific gravity at 60° F.	1.20 to 1.25	1.10 to 1.20	1.10 to 1.15	1.17 to 1.22
Viscosity	High	Medium	Low	Low
Free carbon (insoluble in benzol) per cent	18 to 30	10 to 20	0.4 to 5	2 to 12
Distillate, per cent. by volume, on distilling to a medium grade of pitch	20 to 30	25 to 35	30 to 40	25 to 35
Per cent. of pitch by volume (medium pitch) plus losses .	70 to 80	65 to 75	60 to 70	65 to 75
Tar acids, per cent.	1.6 to 3	3 to 5	7 to 8	0.4 to 2.5

The graph (Fig. VI) illustrates the general range of the distillates from each class of tars, in specific gravity.

Specific gravity is undoubtedly one of the most valuable indentification methods on all hydro-carbon materials, especially in connection with the fractional distillation. On the other hand the strict application of test to crudely taken fractions often leads to misjudgment and difficulty. When more fully developed the test has great possibilities both in control and research work.

TABLE III.

SERIES OF SAMPLES OF REFINED TAR MADE FROM SAME RAW TAR.

Sample No.	Free carbon Percentages.	Distillation Total to 315° C.	Melting Point ° F.	Schutte Penetrometer Sec. at ° F.		Viscosity Engler 100 cc. at 100° C. Sec.	Float Test at 50° C. Sec.
5	12.1	21.8	.....	29	40	94	34
7	12.0	19.2	.....	108	40	127	38
8	14.0	16.4	.....	114	50	159	58
9	14.4	14.9	86.9	85	60	208	75
10	17.2	12.7	99.7	90	70	335	110
11	18.2	10.4	108.7	88	80	431	170

Table III shows an interesting comparison of the values of different methods of testing the consistency of refined tars and soft pitches. There is no one method that can be applied throughout the range from a crude or dehydrated thin tar to a pitch suitable for say road binder or roofing. As we go from liquid to semi-solid and solid mobile materials, the limits of the orifice viscosimeter are soon passed and hybrid methods such as the "float test" which determines neither viscosity or melting point but a

mixture of both qualities, seems to be the only feasible method for use through a certain range of consistency. These methods all involve time and temperature; there is, however, an important distinction between melting point, in which the temperature is raised at a fixed rate to the point at which

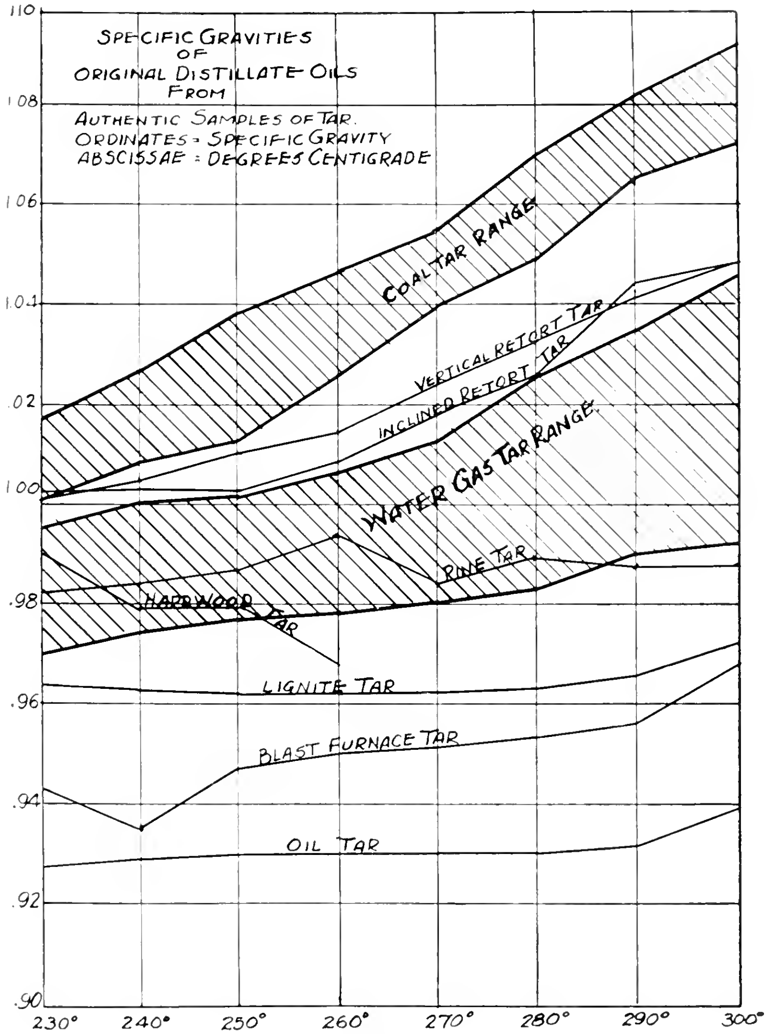


Fig. VI.

the material becomes so soft that its cohesion no longer supports it, and the float, penetrometer and viscosity tests wherein the temperature is fixed and the time required for the material to lose cohesion is the determinable point. Therefore in choosing a method for testing the consistency of semi-solid bitumens, regard must be had not only to the range of limitations of the method's adaptability, but to the question whether it is desired to

determine the behavior of the material at a certain temperature, or the temperature at which the material will behave in a certain way.

A critical study of Table IV would take us far into theoretical speculation, but it is clearly shown that materials of widely varying free carbon content having the same melting point, exhibit varying consistency characteristics when measured by the float or viscosity test.

TABLE IV.

REFINED TARS — RELATION OF VISCOSITY TO CARBON CONTENT.

Sample No.	Free carbon Percentages.	Melting point ° F.	Schutte penetrometer at 80° F. Sec.	Engler 100 cc. at 212° F. Sec.	Float test 212° F. Sec.
1	1.4	110	42.2	302	158
2	14.5	109	80.1	298	192
3	39.6	112	144.9	739	337

APPLICATION OF ANALYTICAL DATA.

Can we apply any of the foregoing data to the technical use of tars and tar products for pipe coating?

Ten years ago I first gave some attention to the question whether or not there ought to be a specification for a refined tar product for coating cast-iron pipe and fittings; I found that at practically all the foundries crude coal tar was being used. The method of coating varied somewhat, it was usually developed by experience and not marked by close control. I came to the conclusion that the coating could probably be improved by —

(*a*) Closer temperature control of both castings and bath.
(*b*) Adoption of some method for testing the consistency of the coating from time to time and keeping it uniform.
(*c*) Specifications for the coating that would insure reasonably uniform consistency and freedom from excess water.

It did not seem to me at that time that the last named requirement was of greater importance than the other two.

No doubt coating technique has been improved during the last ten years; most industries are making progress. I know that your Association has been giving attention to the problem and that tentative specifications for pitch for pipe coating are under consideration.

You may ask — Is pitch a better material for coating pipe than crude coal tar? If so what should be the melting point of the pitch? What is the meaning or significance of " free carbon " in tars and pitches? Should the origin of the tar be specified, that is — gas works, coke oven, etc?

The tars first used for coating pipe were necessarily horizontal gas works coal tars, as the by-product oven, the vertical gas retort and the

carbureted water gas process had not been introduced. In the early days of gas-making fire clay retorts were used and the first important change in the character of coal tar occured when fire clay was replaced by silica retorts. With the latter higher heats were employed and tar was produced of very high viscosity and high free carbon content.

We have already shown that the newer types of tar, i.e., coke oven, vertical retort and water gas tar are thinner and of lower free carbon content than the horizontal gas works tars.

Undoubtedly the best coating is not obtained when very thin tar is used — crude water gas tar or crude vertical retort tar makes a very poor coating, lacking body. In order to obtain a coating having the consistency and covering power of a medium gas works coal tar, most of the tars now available must be modified by distillation, or reduced to the proper consistency. Either coal tar or water gas tar may be reduced to any desired consistency but it is doubtful whether water gas tar should be used for pipe coating as its resistance to chemical attack and its life under conditions of service have not been well established.

What happens when a hot casting is dipped in tar? The object of the process is to obtain a thin but complete coating that will dry in a short time, adhere strongly to the pipe, be resistant to abrasion and finally protect the metal from corrosion. If crude tar is used the heat is sufficient to drive off enough of the more volatile oils so that the remaining film or coating is pitch. If pitch is used to start with, either higher temperatures must be employed or a thicker coating will result. I do not believe there is any merit in a thicker coating per se — on the other hand a very thin tar may produce a coating so thin as to be non-protective and unduly brittle. I am inclined to the opinion that what is needed is a refined, i.e. distilled tar with reasonable limits as to viscosity and free carbon.

The viscosity limits should be specified at an elevated temperature, say 100° C. approaching that of the bath. What does free carbon signify? The term is a misnomer. Free carbon means matter insoluble on hot extraction with benzol. It is not "free carbon," but a mixture of difficultly soluble and insoluble compounds of high carbon content, but containing some hydrogen. Tar is a product of destructive distillation which means that the vapors distilled out of the coal are partially decomposed and the result is a mixture of hydro-carbons with some oxygen and nitrogen compounds which were not present as such in the coal, but are formed in the retort; "Free Carbon" so called is an index to the amount of decomposition that occurs. Tar obtained from coal under conditions unsuitable for decomposition, for example, under high vacuum with rapid removal from the retort would be entirely different from our commercial tar. It would contain a lot of paraffin compounds and phenols and would be thin, and oily with a very low pitch content.

Free carbon in the specification is simply a means of providing for tars that have been produced at neither too low nor too high heats. Lack

of it indicates a thin tar of inferior covering capacity, too much, a thick material difficult to handle and settling out in the treating vessel or bath.

I do not believe apart from specifying that the tar should be obtained from the carbonization of bituminous coal, that its origin need be specified if the proper limits for consistency and free carbon are arrived at. Uniformity is what is wanted and it is the tar distiller's job to produce that uniformity by selecting and combining his tars, and processing the mixture to obtain the desired product.

The tar producer cannot insure this, and while tar from one source may run very uniform for a long time it may and in fact often does change profoundly without any warning as the requirements of coke and gas vary.

It has been the history of material specifications that as we approach perfection the requirements for the finished product become more important than the question of where the raw material originated.

Discussion.

Mr. H. T. Miller.* We know that the wide range between the melting point and the brittle point of asphalt is very large, but in my experience the range between the melting point and the brittle point of coal tar has been very narrow. Has Mr. Church found any wider range on coal tar between those two points?

Mr. Church. There is no doubt but that we are seeking for a material which combines the good qualities of coal tar and those of asphalt. The acknowledged resistance of coal tar to chemical reaction, its long service, its absolute waterproofing capacity, with the physical properties, the gentleman speaks of, that asphalt possesses—that is, lack of susceptibility to temperature changes — unfortunately, that animal has not been discovered yet. It seems there is something inherently different in the composition of materials which have a low susceptibility factor. The reason that they have the low susceptibility factor — that is, that they resist temperature changes — may be allied with the reason why they do not resist chemical reactions as well as coal tars. In other words, they may be more readily oxidizable. There are some indications that way. But I can't say that we have really produced coal tars having a very markedly improved range of resistance to temperature changes, although by selection and by proper refining we can, of course, accomplish something in that direction. In other words, some tars are better in that respect than others.

I am afraid that is not a very satisfactory reply to the question, but it is the only one I can make at the present time.

President Barbour. Is there any possibility of combining some per cent. of asphalt with the tars in order to widen the temperature differential?

* Of National Tube Co.

Mr. Church. That has been tried, and it has been done to some extent. We have had specifications in one or two cities for years for a mixture of coal tar, pitch and asphalt for paving-block filler. We have tried it ourselves and endeavored to improve some of our roofing products. I can't say that the results have been extremely encouraging. There is a limit to the percentage of asphalt that can be mixed with coal tar — that is, from the standpoint of getting a homogeneous compound. Some asphalts can be mixed in greater proportion than others. Those having important aromatic compounds can be used to a larger extent than those which are high in paraffin compounds. It is worse than useless to mix an asphalt obtained from the reduction of a paraffin base oil, with coal tar, because you only get a mess, but a certain proportion of a properly selected asphalt can be mixed, and the results are somewhat encouraging in some cases. But I have not seen enough evidence of great improvement to warrant recommending that additional expense in pipe coating.

Mr. S. B. Brown.* Supposing we have selected a proper tar. Is there anything to be gained by its being applied to the metal so that it will be hard when the metal is cold? In other words, have we lost anything by the hardening of the coating, or is the coating which is semi-plastic, a little sticky perhaps, better than one which is hard? Of course I understand that you can take the same tar, and by a different temperature treatment get either a plastic or sticky or an enamel-like finish. Is there any difference in the desirability as between the two? Is it more desirable to have it plastic or not from a coating standpoint?

Mr. Church. It is very undesirable to have pipe hot enough to dry the coating too rapidly and leave an extremely brittle coating. I think that overheating the pipe is probably more dangerous, so far as the life of the coating is concerned, than underheating it. I do not think there is anything to be gained by having the pipe higher than 300°. Of course if you dipped an absolutely cold pipe in hot tar it would not dry for a very long time; you would have a pipe which you could not handle, as it would be too messy. I think the happy medium is to have the pipe just hot enough so that it will dry the coating slightly tackey. It will eventually set up firm and hard, but it will be slightly tackey for a little while. It can't remain too tackey or there is danger of its being more or less washed. In other words, it has to set up firm enough so that the water will run over it without disturbing the surface coating.

Mr. Brown. My thought in this connection was this: of course the undesirability of a sticky coating is purely connected with the outside of the pipe. The outside of the pipe is not really the point that water works people are interested in. The outside of the pipe won't give any trouble; it is the tuberculation from the inside. If you get a more desirable coating by leaving it a little sticky on the inside, we need not worry about the out-

* Of Warren Foundry & Pipe Co.

side. I notice that they put the wood pipe filler in when it is so sticky on the outside that they have to roll it with sawdust. Does that coating have any better life for that?

Mr. Church. I do not think we can directly compare the wood pipe coating with cast-iron pipe coatings. They use, or did use when I knew about it, a pitch of fairly high melting point, and while it is true that they rolled the pipe in sawdust, that pitch would be very hard without rolling it in sawdust, and it was thought a considerable protection to the coating until the pipe got in place underground. The pitch used was of such high melting point that an abrasion received by the pipe on its way to the job would have damaged the coating considerably if not protected.

I think, however, your coating should not dry too hard. That is a very good point.

THE PROPER TERM FOR WHICH WATER WORKS BONDS SHOULD RUN.

BY CHARLES W. SHERMAN.*

The reasonable or proper term for which water works bonds may be issued has no relation to the laws of Massachusetts or of any other state; and, as I shall show, the laws of Massachusetts relating to the issuance of bonds for water works construction show very little, if any, consideration for the *reasonable* term of life of the property covered by the bonds.

TERM AND AMOUNT OF BONDS INTER-RELATED.

The reasonable period or term of a bond is intimately connected with the life of the property covered by the bond. It is also related to the depreciation or loss in value of the property. Indeed, the two matters of *term* and *amount* of bonds cannot be separated in a discussion of the proper or reasonable length of term of bonds.

PROPERTY COVERED BY BONDS MUST PROVIDE AMPLE SECURITY.

It is self evident that bonds on a water works property, like a mortgage on residence property, should be amply secured; that is, the bondholder should know that the value of the property is sufficient at all times to cover the loan and to repay it at maturity.

Perhaps a further analysis of the conditions of a real estate mortgage will assist in developing a clear comprehension of the matter. Massachusetts savings banks are required by law to limit a loan on such a mortgage to 60 per cent. of the appraised value of the property; and the term is commonly five years. Under any ordinary circumstances the depreciation during this term would not be so great as to leave any question as to the property being sufficient to meet the loan at maturity; and extraordinary depreciation resulting from fire is guarded against by insurance carried in favor of the mortgagee.

Now suppose the borrower should want to give a mortgage for 40 years — which might perhaps be taken as representing the life of the ordinary house. On this basis the house itself would have little or no value at the end of the term of the mortgage; and the lender, if he used ordinary foresight, would not loan more than the value of the land alone, unless some arrangement were made for periodic repayment of sufficient principal to fully cover loss of value by depreciation.

This latter method bears a certain similarity to serial bonds, which will be referred to later.

---

* Of Metcalf and Eddy, 14 Beacon Street, Boston, Mass.

Life of a Water Works Plant.

If a water works plant were like the "One Hoss Shay," which, at the end of its life, went to pieces —

> "All at once and nothing first —
> Just as bubbles do when they burst."

and could be depended upon to render service until that time, then bonds might be issued against it for the term of its life, but with provision for a sinking fund to repay the loan at maturity, since the property would then have only a junk value; or, what is similar in many ways, with serial maturity of bonds for repayment of principal.

But a water works is a complex plant, made up of many items having widely different expectancies of life; and in growing towns it is continually being added to, so that the distribution system, for instance, consists of many parts varying in age from less than one year to the age of the oldest parts of the plant. In this country we have instances of cast-iron pipe 75 years old and still in service; but the *average* age of the distribution system containing these pipes is likely to be less than 20 years, because so large a proportion of the system has been added in recent years.

It is possible to make a fair estimate of the average useful life of an average or typical water works system, and such a figure will be of significance as a basis of comparison, although it should be used with caution in application to any particular case.

In a paper * by Metcalf, Kuichling and Hawley, presented to the American Water Works Association in 1911, they gave the percentages of the total values of a large number of water works plants, represented by the principal parts of such works. Averaging the figures presented I find that the value of the "typical" water works, based upon these particular statistics, is divided as follows:

Land and water rights	6 per cent.
Water supply works	9 per cent.
Pumping works	17 per cent.
Distributing reservoirs	6 per cent.
Purification works	11 per cent.
Distribution pipe system	51 per cent.
	100 per cent.

The useful life of these several parts from the point of view here under discussion may be taken approximately as —

150 years for land and water rights.
75 years for water supply works.
30 years for pumping works.
40 years for distributing reservoirs (including standpipes).
25 years for purification works.
50 years for distribution system (including services and meters).

* Some Fundamental Considerations in the Determination of a Reasonable Return for Public Fire Hydrant Service, by Lenoard Metcalf, Emil Kuichling and William C. Hawley. — Proc. Am. W. W. Asso. 1911, p. 55

Then the average life of the entire system will be $51\frac{1}{2}$ years — or in round numbers, 50 years.

Note: The U. S. Census Bureau "Uniform Accounts for Systems of Water Supply" (1911) states:

"Until further study and experience or a series of inspections and appraisals at fixed intervals furnish more accurate data, the average life of the various parts of the fixed properties of a water-supply enterprise may be assumed to be approximately as follows: For horses, carriages, automobiles, and laboratory apparatus and appliances, ten years; water meters, service pipes, office furniture and general operating equipment, fifteen years; boilers, steam pipes, and filtration equipment, twenty years; engines, pumping machinery, and wood pipes, twenty-five years; masonry of filtration plant, cribs, iron water pipes, intakes and connections, fire hydrants, standpipes, and buildings, fifty years; reservoirs, tunnels, and aqueducts, one hundred years; and for the water-supply system as a whole, fifty years. All these approximations are subject to modification by reason of any unusual conditions which may shorten or prolong the life estimated above."

The Committee on Depreciation, of the American Water Works Association, in its final report,* suggests;

	Years
For storage reservoirs, dams, and large aqueducts	75 to 150
For cast-iron pipe of large diameter	75 to 125
For cast-iron distribution pipe	30 to 90
For wrought-iron distribution pipe	25 to 40
For services	15 to 80
For distributing reservoirs	50 to 75
For standpipes	30 to 60
For meters	20 to 30
For pumping machinery	15 to 60
For boilers	15 to 30
For filter plants	15 to 50
For buildings	20 to 60

The Committee of the American Society of Civil Engineers on Valuation of Public Utilities † gives on page 1559 some data upon life of water works structures which had been abandoned. As would be expected, these related to works which had been outgrown or otherwise superseded, and therefore had much shorter lives than would normally be the case. The figures are therefore of no significance in this connection.

The average figure of 50 years' life for a "typical" water works plant is of no direct use, since it presupposes that all items of the plant are new at the same time, and that no renewals are necessary. Starting with an entirely new plant, of the "typical" character assumed, it does represent the average expectancy of life; if no extensions are required after 5 years the remaining life will be 45 years, but if extensions have been required the

* *Journal Amer. W. W. Asso.*, 1919, p. 85.
† *Trans. Amer. Soc. C. E.* 1917, p. 1311

average remaining life may be 46 years or more. The *remaining life* of the plant does not decrease uniformly from 50 years to 0, since the effect of extensions and replacements which add new elements to the plant at frequent intervals is to reduce progressively the rate at which the remaining life decreases. Indeed, after a time the remaining expectancy of life no longer decreases but remains substantially constant.

That such would be the case becomes obvious from a consideration of the conditions; and that it does as a matter of fact, has been amply proved by the figures of the large number of valuations of water works which have now been made of plants of all sizes and a wide range of ages.

Average Remaining Life is Proper Term for Bonds.

The average expectancy of life remaining after it no longer decreases is then a suitable term for which bonds may be issued in the case of the assumed typical plant. This remaining life of the plant will be the same now, next year, and five years from now.

The above statement is not precise in its application to any particular works, but is nearly so with any growing plant, or even in one whose growth has ceased, provided that replacements and renewals are made as they become necessary. That is to say, the effect of the long life ahead of new plant added for renewals and extensions will, *on the average*, offset the lesser remaining life of the old plant due to increasing age. In practice the expectancy of future life generally decreases gradually during a term of years, while only minor extensions and renewals are made, and then increases abruptly when important additions to plant are made; the average result corresponding to a relatively uniform expectancy of life.

Determination of Remaining Life.

The average remaining life expected is rarely estimated or stated in reports of valuations. The amount of the accrued depreciation upon existing plant is, however, practically always stated, and its ratio to the reproduction cost (or original cost) of existing plant is easily obtained. The relation between accrued depreciation and elapsed proportion of the total life is a direct one; and if the average total life can be taken as a constant — say 50 years — the remaining life follows directly.

For this estimation the *total* accrued depreciation, including that on abandoned structures, should be used, and compared with the total cost, including that of the same abandoned structures. The figures should be based upon complete records for works of a considerable age, not less than 20 years; figures for works of which the record of abandoned structures is lacking or incomplete are less satisfactory, and require some adjustment before being used.

A sufficient number of complete records, covering both large and small works, automatically includes the *normal* percentage of complete deprecia-

tion, due to accident, obsolescence, or other causes resulting in less that the usual life for some structures, and the figures obtained from these records furnish a basis for approximate adjustment of data covering only the depreciation of existing plant.

In a paper entitled "Practical Checks upon Water Works Depreciation Estimates"* Mr. Leonard Metcalf has submitted a table of "Depreciation Records of Some Old Water Works" which contains eleven such complete records; and other data not included in the published paper bring the number to thirteen. The total accrued depreciation in these thirteen cases averages 19.7 per cent., the range being from 7.2 to 27 per cent. Omitting the lowest record as abnormal, in view of its divergence from the others, as well as the known circumstances making for a low depreciation, the range is from 13.3 to 27.0 per cent. and the average 20.7 per cent.

Assuming that depreciation accrues on the basis of a geometrical progression, corresponding to the growth of a sinking fund earning 4 per cent. interest, a total accrued depreciation of 20.7 per cent. on a plant of 50 years' total life, corresponds to an age of 20 years, and a remaining life of 30 years.† The range of depreciation from 13.3 to 27.0 per cent. corresponds to remaining life of 36 to 26 years.

On the basis of these figures the conclusion is obvious that under normal circumstances the fair term for water works bonds is 30 years, and that in individual cases it should seldom be less than 25 or more than 35 years.

Residual Value.

These same figures of accrued depreciation indicate that there is still remaining in normal works a value of approximately 80 per cent. of their cost, the range being from 73 per cent. to 87 per cent. (The figures given have been based upon reproduction rather than original or actual cost, but the proportions would differ but slightly if at all if figures of actual cost had been used.)

In references to cost or value in this paper the physical plant, only, is meant. Items of value not represented by the plant are omitted from consideration as having no bearing upon life of the property, or upon the part of the value which may properly be covered by bonds.

An examination of the records of accrued depreciation for a large number of other water works, mainly those for which there is no record of abandoned property, indicates that the above figures are conservative. After adding reasonable allowance for the effect of abandoned property, there seems to be a decided majority of plants in which the accrued depreciation is less than 20 per cent., and but few in which this figure is materially exceeded.

* *Journal Amer. W. W. Asso.*, 1919, p. 371

† If the average total life were 60 years, the remaining life corresponding to 20 per cent. depreciation would be 33 years; and for a 70-year total life, the remaining life would be 35 years.

Reasonable Term for and Amount of Water Works Bonds.

It therefore appears that the fair or reasonable term for water works bonds is 30 years, and that 80 per cent. of the cost may be covered by bonds, which will be suitably secured by the property covered.* Under exceptional circumstances the term may be reduced to 25 years and the percentage of cost to be covered by bonds to 75.

Municipal Water Works Bonds.

In the case of bonds of municipal works, the property is not the sole security for the bonds, as the credit of the municipality is pledged. The bondholder is, therefore, suitably safeguarded even if the entire cost of works be raised by bonds. Indeed, such procedure is usually the only one possible in the case of new works, and is justified by the fact that the anticipated life of the works at that time is 50 years or more; but in the case of enlargements or extensions it is certainly the case that conservative financing would require that such works be self-supporting and that neither the amount nor term of bonds be greater than would be proper in case of private corporation ownership.

Massachusetts Laws Affecting Municipal Water Works Bonds.

In Massachusetts, the laws regulating the issuance of bonds for municipal water works have been framed from the point of view of limiting and regulating municipal indebtedness, without sufficient consideration of water works as a utility which should be self-supporting, and the financing of which should therefore be subject to the same conditions as would be proper under private ownership. This condition resulted from the fact that a number of cities and towns had issued bonds far beyond reason, and in some of them water revenues had been diverted to other municipal departments while construction of any kind, including replacements and renewals, was financed by bonds. In an attempt to cure this condition laws were enacted which have caused considerable hardship to those responsible for water works financing in this state.

I had occasion to comment upon these laws before this Association in 1916, when Wm. S. Johnson, Henry A. Symonds and myself submitted a paper † discussing these provisions and their effect in detail, and offering suggestions for amendments which we were then attempting to have enacted. We succeeded in getting only a small portion of the relief for which we asked, and the present law is substantially the same as it was at that time. It is codified in Chapter 44 of the General Laws, Sections 8, 9, 17, 19, 20 and 22. The most significant portions are as follows:

* This statement must not be taken to mean that it would be good corporate financing to issue bonds to the extent of 80 per cent. of the physical property; nor that items of intangible property should be omitted from capitalization.

† Municipal Water Works Financing in Massachusetts, as Affected by Recent Legislation, JOURNAL N.E.W.W.A., Vol. 30, p. 779.

"Section 8. Cities and towns may incur debt, outside the limit of indebtedness prescribed in section ten, for the following purposes and payable within the periods hereinafter specified":

. . . .

"(3) For establishing or purchasing a system for supplying the inhabitants of a city or town with water, for the purchase of land for the protection of a water system, or for acquiring water rights, thirty years.

"(4) For the extension of water mains and for water departmental equipment, five years."

. . . .

"Debts mentioned in clause (1) of this section shall be payable as provided for in sections four, five, six and seventeen. Debts for all other purposes mentioned in this section shall be payable within the periods above specified from the date of the first issue of bonds or notes on account thereof, and may be incurred in accordance with the laws relating to such purposes, so far as they are consistent with this chapter. Debts, except for temporary loans, may be authorized under this section only by a two thirds vote."

. . . .

"Debts mentioned in clauses (3) and (4) of this section shall not be authorized to an amount exceeding ten per cent. of the last preceding assessed valuation of the city or town."

(General Laws of Massachusetts, Chap. 44, pp. 361-362)

Under this law it is impossible to borrow money for water works extensions for a longer term than 5 years, so that whenever conditions arise making it impracticable to finance necessary construction by 5-year serial bonds, special legislation must be obtained.

I grant the desirability of some central authority maintaining close control over municipal financing, and that some method must be provided to prevent a misuse of power in this matter, such as formerly existed in some cases. Perhaps this could be accomplished in part by a general law providing that all revenue from water works operations should be devoted to water works purposes and not diverted to other uses — it being under. stood, of course, that payment of interest and principal upon debts contracted for water works construction, is a proper use of water works revenue.

Special Legislation Undesirable.

With regard to the propriety of bond issues and the amount and period of the bond issue, it seems to me that this is a subject which ought not to be referred to the Legislature. Its proper decision demands a detailed knowledge of conditions affecting public utility operation, financing and management, which the Legislature and its committees cannot have. Moreover, it is extremely undesirable that the time of the Legislature be wasted in considering appeals for special legislation, attempting to analyze the propriety and desirability of the laws desired, and cumbering the statutes with special legislation applicable only to particular cases.

The sensible manner of handling subjects of this kind would seem to be a general law referring all such cases to the Department of Public Utilities, which now has jurisdiction over the issuance of bonds and stock by private corporations operating public utilities, and which is best fitted of any State authority to deal with this subject.

In view of the fact that the credit of a municipality is pledged, and not merely the particular works for which bonds are to be issued, it is probable that some general requirements limiting the power of the Department of Public Utilities to approve bond issues in accordance with the financial standing of the particular municipality, would be advantageous;* but the general principle of referring the whole matter of water works financing—municipal as well as private—to the Department of Public Utilities, seems to be sound and to the advantage of the community as a whole.

Present Situation of Belmont.

An instance of the hardship imposed in attempting to comply with the present law, and the resulting necessity of applying to the Legislature for special legislation, is afforded by the present conditions in the town of Belmont. The water works of this town have been self-supporting for many years, and under conditions existing before the war ordinary extensions were easily taken care of out of surplus revenue, in addition to paying interest and bond requirements upon the water debt.† During the war construction work was kept at a minimum and a material balance was accumulated. As such a balance is always looked upon with envious eyes by town officers anxious to keep the tax rate at a minimum, authority of the town was asked and obtained, to transfer $5 000 to the water sinking fund, thus building up the fund to such a point that it, with its accumulations will take care of all the sinking fund bonds outstanding, without further contribution. Five thousand dollars were also appropriated to the general funds of the town, since at that time there was no indication of the abnormal demands of water works extensions which were soon to develop.

The growth of Belmont since the termination of the war has been at a phenomenal rate. This is indicated distinctly by the number of services installed in recent years, as follows:

Year.	New Services.
1918	19
1919	59
1920	100
1921	136
1922	210 (approximately)

The population, which was 10 749 according to the census of 1920, now approximates 14 000.

*Perhaps the provisions of the General Laws quoted above, by which the total water works debt is limited to 10 per cent. of the assessed valuation, is sufficient, although the percentage is too high.

†But the total amount of bonds outstanding was only about $55 000, against works which had cost upwards of $200 000.

This growth has been accompanied by a corresponding real estate development which has demanded material extensions of the water works distribution system. The amount expended for construction during each of the last four years has been approximately as follows:

1919	$5 785	1921	$30 739
1920	23 318	1922	31 000

Prior to the war, and under normal circumstances since the war, there would be available from water revenue, approximately $13 000 each year for extensions, after meeting operating and fixed charges. Since 1919, however, the actual cost of the extensions required has ranged from $23 000 to $31 000, and there is no indication that this expense will be materially reduced in the near future.

In 1920 nearly $11 000, in addition to the surplus for the year, was required for construction. This was taken from the balance brought forward from the previous year, thus reducing the balance with which the department began the year 1921, to approximately $9 000, and as no further collections were made until after June 1, this sum was obviously inadequate to the needs of the department.

In 1921 approximately $13 000 surplus revenue was devoted to construction, and in addition $15 000 were borrowed on 5-year serial bonds, in accordance with the general law. The total cost of construction was, however, nearly $31 000, with the result that the department's balance was still further depleted to approximately $6 500.

During 1922 it became necessary to repay $3 000 on the serial loan of 1921, in addition to the increased interest requirements, so that in spite of larger earnings the surplus available for construction was reduced to about $11 000. Twenty thousand dollars additional was borrowed, again on 5-year serial bonds, providing a total of about $31 000 for construction, which is approximately the amount actually expended. The balance at the end of 1922 is therefore substantially the same as that with which the year was started.

With $3 000 of the loan of 1921 and $4 000 of the loan of 1922 maturing in 1923, the surplus available for construction will be reduced to approximately $6 500. The construction requirements are not likely to be less than those of 1922 and may be considerably increased. The Commissioners estimate $35 000 as the probable construction cost. In view of the depleted condition of the balance it seems desirable to borrow $30 000 of the estimated requirement of $35 000, thus allowing a small addition from surplus revenue, to the working balance.

This money, like that borrowed in 1921 and 1922, might be obtained on 5-year serial bonds, and the needs of 1923 would thus be met without particular difficulty. It would, however, add a further sum of $6 000 per year to the amount annually required for repayment of bonds, beginning in 1924, and there would therefore be only about $1 500 of surplus earnings available for the construction of that year, and it would become still more necessary to borrow substantially the full amount required for construction.

The point has obviously been reached where it is a distinct hardship to borrow further on 5-year bonds, and where it is necessary to apply to the Legislature for special legislation, allowing the issuance of bonds for a longer term. In view of the comparatively insignificant amount of bonds outstanding against these works, ($78 500 as compared with a total cost of about $300 000), it is hoped that this legislation can be obtained.

Conclusion.

Summarizing the statements in this paper, its conclusions are:

1. The average life for a "typical" water works plant in this country is about 50 years. It will rarely be less than this in individual cases, and may be as much as 60 years or more for some works.

2. Complete records of depreciation, including abandoned structures, of a number of water works plants of considerable age show that the total accrued depreciation of the physical plant of such works is about 20 per cent. of the cost. Departures from this mean are not great. Records of depreciation suffered by the plant still in service, modified by a suitable allowance for plant abandoned, confirm this as a reasonable normal figure.

3. The corresponding average age for works of 50 years' life is 20 years, leaving 30 years average remaining life. If the average useful life were 60 years instead of 50, the average age would be 27 years and the remaining life 33 years. Thirty years is a fair estimate of the average remaining life of any water works plant in normal condition, and therefore a proper term for which water works bonds should run.

4. If the works have suffered a depreciation of 20 per cent. including abandoned property, there is a residual value of 80 per cent. of cost of the physical plant. Water works bonds may therefore safely be issued up to 80 per cent. of the normal cost of the works.

5. Municipally owned water works should be self-supporting, and their financing should be on the same general basis as that of private corporations.

6. The clause of the present Massachusetts law which limits bonds for the extension of municipally owned water works to a term of 5 years is illogical and burdensome, and should be repealed.

7. Special legislation for particular cases, made necessary by the existence of the 5-year limit, is undesirable from every point of view.

8. Suitable control over municipal bonds for water works purposes can be exercised by requiring the approval of the Public Utilities Commissioners in exactly the same way as for bonds of a private water company.

9. Misuse of water revenues can be avoided by legislation limiting their uses to water works purposes.

Note: Since the presentation of this paper my attention has been called to an editorial article entitled "Municipal Loan Purposes and Periods in England and the United States" in *Engineering News* of November 2, 1905, p. 463. Besides a statement of the conditions under which loans could be made in England, it includes a very interesting and suggestive discussion of the principles which should govern in such cases, and might well have provided the text for such a paper as this: but most of the data upon which my conclusions have been based were not available at that time.

Discussion.

The President. As stated in the notice of the meeting, we had hoped to have with us today the members of the Special Commission on Municipal Taxation. They have, however, both this morning and this afternoon, hearings in connection with the cities of Fall River and New Bedford, and are unable to be present. They have just now telephoned me, saying that they would very much like to meet the representatives of this Association at some special meeting to be called for the purpose, and that they are distinctly interested in our viewpoint on this problem. I presume we shall be very glad to appear before them.

While we have not been able to bring here the Commission, we have with us the principal hurdle over which we must climb in this financial problem, Mr. Waddell — Director of Accounts of the Department of Corporations and Taxation. I know we all want to hear from Mr. Waddell.

Mr. Theodore N. Waddell. Mr. President and Gentlemen: I am in a very fortunate position — fortunate, I think, for me, in that I have more or less of a rhinoceros hide. I am always on the wrong side of the question. However, I would like to say that I believe my heart is in the right spot.

Now there are certain conditions which I meet with that are not fully appreciated by those who work from a scientific standpoint. I am not in a position, nor am I disposed to believe that the points which have been mentioned are open to criticism. We have, however, a situation surrounding us, political and otherwise, that must be met.

I want to explain briefly the 5-year clause of the law relating to the extension of water mains and for water departmental equipment, and give some experiences I have met with concerning its operation. When a report of the examination relative to municipal finances was made by our department in 1912, I thought it would be a good idea to have our suggestions passed upon by an organization that was then holding its meeting, and I therefore suggested that we submit certain of these recommendations to the treasurers of the various cities and towns at their meeting. We had a very pleasant reply from them, (?) giving unanimous disapproval of the recommendations. Later, another conference was arranged and then a unanimous vote of approval was given.

Now, on the 5-year proposition. The committee, at the time the matter was considered, hesitated to make provision for extensions into new territory, believing that cities and towns should come to the Legislature each and every time an extension was desired. Now, I am always satisfied with a bite out of an apple if I can't get the whole apple, and I am convinced that in fully 50 per cent. of the cases where they have used the 5-year provision, it has been ample. I am thoroughly convinced, however, that the present general law is inadequate to meet all of the needs of our municipalities. You are familiar, I presume, with the fact that there

is a statute which requires me to report to the Committee on Municipal Finance on every bill calling for the borrowing of money. It is rather embarrassing to make a report against one's own judgment, but these reports are necessarily statements of facts as I learn them and it is left for the committee, after hearing all the evidence relating to the subject in question, to act as it deems proper. But it seems absolutely unfair to me for one city or town to be authorized to borrow for 30 years; another for 15 years; another for 20 years; and perhaps another for 25 years. It is absolutely unfair and unreasonable. I personally believe that annually recurring costs, whether they be for water main extensions, building schoolhouses, or building streets should be paid direct from revenue. We are told to let posterity pay the costs, but posterity has several troubles being passed down to it. The policy of paying as you go, for at least the annually recurring costs, is, in my opinion, sound.

Now, as to the cost of interest — I was on the unfortunate side on that in 1916. I stated to the committee, or to the Special Committee of the Association which appeared before the committee, that I believed they were getting what they did not want and were not getting what they really wanted. Now, that law has been on the statute books some 6 years and has been availed of probably three times in the 6 years. In that 6 years, I think it is a safe assertion to make that there have been at least 50 to 75 special bills passed.

The reason I speak of that 5-year exemption is a matter of psychology. When you are getting something now, something that is of great benefit, you pay for it willingly; but we find that we have outgrown many of our systems — the street mains need to be relaid and it is not practical to relay them from water revenue, neither is it possible, under the general law, to relay them by a loan. I firmly believe that there should be some provision for meeting this difficulty, and I had the audacity to recommend, when the consolidation of the laws was being made, that an amendment to what is now Chapter 44 of the General Laws be considered by providing that cities and towns might borrow for from 15 to 20 years for laying or relaying street mains of 6 or 8 inches in diameter. Now, I haven't any idea whether that is scientifically correct or not, but I have an idea that such an amendment would relieve the Legislature of a great many special bills. I also recommended that provision be made for the construction of reservoirs and standpipes, with a like term for loans. Under the General Law, as I understand it, you cannot borrow for that purpose at all — not even under the 5-year provision.

Now, to show how things work out — and no doubt there are gentlemen here who have been in the Legislature, and know the legislative machinery, so that it does not seem quite right or proper for me to criticise them — but in the present year, 1922, I had this experience. A certain person came in who had been both in the House and the Senate — a very pleasant gentleman to meet and a very able man — and he said: "We

are up against it in our water works; we must have a special bill through." I therefore drafted a bill for him in the usual broad form, and this was reported and enacted in a very short time. It was impossible for me to tell the standing of the past loans of the town in question, but in following them through I discovered, after the Legislature had adjourned, that there was a special act on the statute books allowing borrowing for the purpose in question that had been there for, I guess, some 10 years, and it had not even been touched — not a single dollar had been charged against it.

In 1913, within a few weeks from the passage of the General Municipal Indebtedness Act, one of our cities secured a special act which permitted it to lay a large main from a reservoir down into the city. It was recognized by the committee in 1912 that water legislation could be sought constantly by the cities and towns. I know, in fact, of only one city that I can recall that was absolutely refused legislation. This was refused, I think, for the reason that one of the petitioners made the statement: "You see we have the lowest water rates in the State," giving their minimum charge at $6.00, and I am not sure that this rate was not the maximum. I think the charge was a flat $6.00 Well, they did have a low rate, and naturally the water works went to pieces, and so far as I know it is about in that condition today. It is impossible for them to give an adequate supply of water. I can recall only that one city that was absolutely refused legislation.

Now, there is no question but what special legislation will be granted under proper conditions. I agree with you that it ought not to be necessary to seek such legistation. Unfortunately, I am in a position where the majority of the members — in fact, the committee — are in disagreement with me. I was in hopes, and I expressed to the President of your Association, that he would go before the commission now sitting to urge, and that the commission would recommend, legislation that would relieve the Legislature of a number of these special acts. I know they regret very much that they could not be present at this meeting and get first hand from you your feelings in this matter, but it was stated just before adjournment of the commission today that they hoped that a committee of your Association would appear at a meeting and discuss this question from your standpoint. Personally I would like to see the legislation broadened so as to permit borrowing for a reasonable period of time for street mains, for reservoirs, and for standpipes. I do not say that that would cure all of the evils, but it would be very helpful and would reduce the present special legislation to a minimum.

So far as ordinary extensions and their connections are concerned, it seems to me that it is perfectly right and proper that these annually recurring charges should be put into the tax rate. Now, when you consider that the interest cost on a 5-year loan is practically 12 per cent. or upwards, on a 10-year loan is 22 per cent., on a 20-year loan is 42 per cent. plus, and on

a 30-year loan is 62 per cent. — or under the plan with the 3-year exemption is 70 per cent. — of the original cost, the interest is quite an item. And I think, furthermore, when you realize that the bonds of Massachusetts municipalities are selling on the market at a lower rate than those of any other State in this Union some credit is being given in return for the splendid Municipal Indebtedness Act of 1913. It is not perfect by a long ways. It is not easy to amend; but I sincerely hope that certain amendments can be obtained that will relieve special legislation.

I do not question for a moment the intent of the members of the Legislature, because they are trying to carry out in principle some of the laws which were enacted as the result of special study and I hope they will continue to do so. However, we must recognise that there are certain weaknesses in the law, and I would like to see them bolstered up. It is not at all pleasing to me to have all the dirty linen of all the cities and towns in the Commonwealth washed out at a public hearing, and we always have more or less of it at such hearings.

In comparing municipal plants with private plants, there is one thing I think you ought to bear in mind. No private plant will extend mains where no appreciable return will be received for many, many years. Municipal plants are very likely to extend mains where nothing like adequate returns will be received, and for that reason I question whether or not it is fair to assume that a municipality ought to be allowed to incur debt for construction, for capital purposes, to the degree that you naturally will expect in private plants. I think it has a bearing, knowing the town governments as I meet with them. In my own town, to my knowledge, we have not borrowed for water works for 12 years. I think they have a very comfortable working balance. We have a very reasonable rate, but I feel sure that 100 of the fire hydrants could be eliminated in our town if the existing street mains were replaced by larger mains. How long present conditions will continue, I am not sure, but I do know this — there is not a great deal of advantage in having an extra pump come in to fight a fire when one pump has just about milked the pipe dry. We do outgrow water mains, and very few, if any, municipalities are willing to take the criticism which would follow the installation of new mains that would be adequate for 50 or 75 years. I think it would be almost impossible to get them to do it. So that you have to recognize that you have not only depreciation on account of the life of the mains, but you have a further depreciation on account of necessary renewals.

I did not intend to say very much except to call your attention to the Act of 1913. The 5-year clause particularly was not put in with any idea that it corresponded to the life of the mains, but it was the only relief that it seemed possible to get at that time. It is a good deal like the 25 cent clause on departmental equipment. I have been laughed out of court several times on the matter, and the only way you could convince the committee at that time was to say to them: "Here is a town of a half

million valuation; they want a road roller, and towns do need road rollers. Is that town going to put $7.00 or $8.00 on the tax rate to buy a road roller?" Now, a dollar is a dollar, and it is just as much a dollar in the small town as it is in the city. You take the 25 cent clause in Boston with its one and three-quarter billion — they have to get three or four hundred thousand dollars in equipment before they can borrow a nickel, but when you get into the small towns, they have only a very small amount in the tax rate, so that relatively it was all right. I think it has worked out very comfortably for all our municipalities.

But whatever the right period is for a loan for relaying mains, standpipes and reservoirs, it seems to me that you ought to arrive at some solution of that problem and thus eliminate, I should say, at least 90 to 95 per cent. of the special acts.

Mr. Sherman. I have been greatly pleased by what Mr. Waddell has said, and to learn that he and I are so very closely in accord. In the last analysis, what he has said and what I have said come pretty nearly to the same thing.

One of my inferences, is that the 5-year limitation on bonds for water works extensions, resulted from a "trade" in the committee. I have no question that some kind of legislation was necessary, but when you compare the particular clause of the law which limits our bonds to 5 years, with the following one which allows 20 years for gas and electric lighting bonds, you see that there is absolutely no consistency between them. Either water works men did not know what was being done, or were not properly represented at the time this legislation was put through.

I think that the term and proper amount of any municipal water works bond issue ought to be fixed with reference to circumstances of the particular case, by some authority which may be considered more or less expert in that line, and which is constantly dealing with such matters. It seems to me the Public Utilities Department is the natural one to have such jurisdiction. Municipal water bonds, although issued to provide funds for some specific improvement, are not secured by any particular part of the works, but by the plant as a whole, and with the credit of the municipality behind them. There is no particular reason, therefore, to limiting the term of some bonds to say 10 years, and allowing perhaps 30 years for others, especially if no bonds for 50 to 75 years are issued when bond purchases are made, or very long lived structures are built. In general, for water works as a whole, 30 years is a fair term for bonds which will be properly secured during their life, if not issued for more than 80 per cent. of the cost of the works.

One other point which Mr. Waddell has stressed — and it is a very important one — relates to the constant diversion by some of our cities and towns of water works revenue to other municipal uses. It is an evil which we as water works men must undertake to cure. It can't go on indefinitely if the water works are to be on a proper basis. Just what

kind of legislation would assist in doing that I am not sure, but I think some kind of a general law could be framed, and I hope it could be passed, which would absolutely prohibit the diversion of such funds.

The water works utility, if owned by a municipality, should be run entirely separate from other municipal affairs. Its earnings should be devoted to the Water Works Department.* The Water Commissioners should be required to establish rates sufficient under ordinary circumstances to cover the interest on debt and the debt retirement requirements, operating expenses, and such ordinary extensions as are, as Mr. Waddell puts them, annually recurring expenses — things that can be foreseen and expected. On the other hand, once in a while the need arises in any growing city or town, for a radical reinforcement of the plant, and borrowing is the only way to properly meet such a contingency. If the sum required is a large one, you do not get great help from your borrowing if you have to repay in 5 years; you do not get as much as you ought if you have to repay in 10 years. Whether it should be 20, 25 or 30 years is perhaps something for argument.

The Legislature can very well establish general principles and limits which must be conformed to, but the Public Utilities Department, or some other competent body, should do the regulating.

Mr. George F. Merrill.† I was very much interested in Mr. Sherman's paper, and I was glad to hear Mr. Waddell bring out the things which he did.

Every water works man throughout the State knows that almost any system that was designed as early as 1872 is wholly inadequate to furnish service to anywhere near the insurance requirements today, and I believe that bond issues should be provided for renewals.

I also think that we need a clearer interpretation of what constitutes a renewal. For instance, in one case I know of it was desirable to lay a 16-in. pipe in a street that only had a 4-in. We were informed that an interpretation was received from the Bureau of Statistics that that would be a renewal and we could not issue bonds on it. However, if we had laid this 16-in. pipe on the other side of the street and left the 4-in. pipe in service where it was, it would have been new construction. That is a point that should be cleared up. I think it would not be desirable to specify in the law the size of pipe which would constitute renewal. In some cases it may be a size of 3 or 4 in. increased to 12 or 16. It is a matter of local conditions.

I also think Mr. Sherman made a very good point in the comparison of the 20-years time of bond issues for municipal electric light and gas plants, with water works issues, and it might be to the point to state that

* In some cases it may be practicable to assess sewer users in this form of additional water rates, and thus provide the money necessary for maintaining and operating a sewerage system without recourse to the general tax levy. Such a practice is not really in contravention of the above principle, but a special form of assessment for sewer maintenance, and the accounts ought to be kept in proper form to show it as such.

† Superintendent Water Works, Greenfield, Mass.

their depreciation is about 10 per cent. while the water works depreciation is far less. It is a rather illogical part of the law.

I think we are getting a good deal of good out of this discussion.

President Barbour. It is a fortunate thing for Mr. Waddell that there are no insurance men here, apparently. This is the first instance I have ever heard of where there were too many hydrants.

Reference has been made to the different methods of handling bond issues for privately owned plants, which come under the supervision of the Public Utilities Commission. We have with us a member of that Commission, and we would like, I know, to hear from Mr. Wells.

Mr. Henry G. Wells. Mr. President, and Members of the Association: There is not very much that I can say to you gentlemen except what appears upon the statute books of the Commonwealth, with which you are all doubtless familiar.

I am reminded a little bit of the famous colloquy between Chauncey Depew and Rufus Choate at a dinner. They were both seated at the head table, and Depew said to Choate: "Well, this is another case of a nickel-in-the-slot machine. You put down a lunch and a speech comes up." Choate replied: "Yes, and sometimes you put down a speech and a lunch comes up." Depew thereupon replied: "Well, it is better to have lunched and lost than never to have lunched at all."

After hearing all the tales of woe from members of the Association, and also from Mr. Waddell, I trust that all of your companies are not in the same situation that some of the other Public Utility companies are in. They tell the story about a railroad out in the middle west, which two men were discussing, and one man said, "Don't you know that railroad is of Divine origin?" "Divine origin?" said the other; "how do you make that out?" "Why," the first man said, "you know in the first book of the Bible it tells about how God created all creeping things."

I trust our companies haven't got in that state yet, although there is some talk about pressure over here on the part of Mr. Waddell.

Some little suggestion was made here that perhaps the municipal plants might like to come under the control of our Department. Now, I assure you, gentlemen, that we are not looking for any more work; we have troubles enough of our own now. About a year ago the Legislature wished on us — by what legislative reasoning I do not know — the enforcement of the so-called "Blue Sky" law. What the sale of securities has to do with public utilities I do not know — the sale of private securities, at any rate; but, nevertheless, we are trying to administer that law, and along with our other duties it gives us trouble enough.

However, to come specifically to the suggestion made by your presiding officer, private water supply companies come under our jurisdiction to the same extent, practically speaking, that gas and electric light companies do.

Reference has been made to the provision relative to municipal gas and electric plants where bonds are issued for 20 years. As to private gas and electric plants and private water companies there is no provision as to the length or period of time. We were told until a short time ago that bonds could be issued up to the same amount as the capital stock: That is, they should be relatively 50-50; that they should bear interest at the rate of not exceeding 6 per cent., and could be secured by mortgage, but should be issued under such terms and conditions and restrictions as the Department might lay down. In view of the financial stress of the past few years that law was changed, eliminating the provision that the bonds should not exceed 6 per cent., and providing also — I neglected to state that these bonds must be issued at par — providing also that bonds which were issued under a pre-existing mortgage could be issued below par if the Department so approved. In other words, where there was an existing mortgage and corporation bonds had been issued at 6 per cent., future bond issues must also be issued at 6 per cent., and under those circumstances the bonds could be issued at less than par. That, I believe, is the general provision affecting gas and electric companies privately owned, and also relates to water companies privately owned. So that any private water supply company petitioning the Department for an issue of bonds comes to us and we turn the figures submitted over to our Accounting and Engineering Departments, and they are gone into thoroughly and under the law we prescribe that those bonds, whatever we allow, shall be issued at a certain rate of interest, and that the proceeds on those bonds shall be devoted to certain specific purposes, usually set forth in the petition.

I think one of the speakers referred to the fact that bonds ought to be allowed to be issued up to 80 per cent. of the value of the plant. I assume, of course, that he is referring in that instance to the municipally owned plants, because as to privately owned plants with an issue of stock outstanding, I do not believe he would agree that they ought to be allowed to issue bonds up to 80 per cent. of the value of the plant. Certainly those gas and electric companies which during the war had an outstanding bond issue of an amount, say, equal to 50 per cent. of the stock, found their credit in a very precarious situation. In other words, the gas and electric companies which had small outstanding debts, as represented either by notes or bonds, during the financial stress found themselves in much better condition and could render much better service to the community than those companies which had large outstanding debts represented by notes and bonds.

Now, of course if the Legislature in its wisdom, and with its power of determining principles, should give to the Department of Public Utilities the jurisdiction over municipally owned water companies, we would assume the burden with as good grace as we could.

But I want to suggest one thing: Having been a member of the Legislature for a considerable period of time, I know you will encounter this proposition: There is always running through that membership an

intense interest in the so-called principle of home rule, and I am afraid you will find that if an attempt is made to put municipally owned water companies under the Department of Public Utilities, you will immediately stir up a cry of centralization and taking away the principle of home rule from those municipalities. I simply want to throw that out as a suggestion, because I have seen that done so many, many times.

I thank you, Mr. President.

Mr. Reeves J. Newsom.* Mr. President, while Mr. Waddell is here to comment on the matter I would like to point out an illustration of the requirements of the water department and its relations to the 5-year term in the Municipal Finance Act.

The City of Lynn Water Department, until 1921, had for its use all of its receipts. As a result of that no money was ever borrowed for anything except permanent extensions to the supply of the system. That is, all the bond issues were 30-year bond issues. Beginning last year the system was changed and a specific appropriation was made for the water works and the receipts were turned into the general revenue. The result was that the size of that specific appropriation was such that nothing but ordinary operative maintenance could be carried on, and it became necessary to borrow money for all extensions to do work. It was impossible to put any services to new houses or install a meter or lay a new main without borrowing money for that purpose. And the result is, of course, that we have had to issue a lot of those 5-year bonds.

Now, Mr. Waddell pointed out the evil of issuing bonds for annually recurring expenditures, and this is an instance of how the city has been forced to do that very thing, because it is not allowed the use of the revenue which it gets from the water.

Mr. Frank E. Winsor.† In applying the conclusions of Mr. Sherman's paper to specific cases, I would call attention to a danger in using general statistics of this kind, which may be overlooked and which should always be borne in mind in fixing the date of maturity of bond issues, namely, obsolescence. The considerable number of water works structures which become obsolete in a relatively short time is perhaps not appreciated by many of us. For example, I have in mind a filter plant of 10 acres which after an average life of less than 20 years will become obsolete, also pumping plants, buildings, etc. which will become obsolete after lives varying from 10 to 50 years. Similarly, parts of a distribution system frequently become obsolete from the necessity of replacing small pipe by larger pipe.

Mr. Waddell. I do not think I made clear the situation under the 5-year statute, and I would like also to make clear the position that I occupy.

* Commissioner of Water Supply, Lynn, Mass.

† Chief Engineer Water Supply Board, Providence, R. I.

It is not my purpose at any time to attempt to influence legislation, except to maintain standards, and it seems to me that your Association must appreciate the proposition that you are facing, and while you may not get your ideal at the outset, if you work in that direction you will arrive at it much quicker than by trying to take everything knowing that you won't get anything.

The pay-as-you-go basis, I would like to say, should be followed, not only in connection with the water works. In my own town, we started off by eliminating borrowing for sidewalks that we could put in the tax rate every year; then we eliminated borrowing for annually recurring costs on the streets, and for annually recurring costs on sewers.

Do not understand me to say that if you have a large project, you should not borrow, because I believe you should; but I am cutting out the annually recurring costs. If you are building schoolhouses every 5 years, you should not have a 20-year loan to pay for them.

I have incessantly advocated an appropriation by the municipality for fire service as well as for department charges. We have always advocated that, and fortunately we get it in most municipalities now. I am not bothered so much as to the separation of the actual cash as you are, naturally, but I am very much interested in showing what is actually being earned and what is actually being expended.

In whatever legislation you seek, I would only say that, if I have any influence, I shall be glad to use it, for I always like to pass along any information I have, believing that by and by we shall, at least, accomplish a part of our ideal if not the whole of it.

MR. SHERMAN. In response to the point raised by Mr. Winsor, I want to say that the statistics of which I made use in arriving at the general conclusion include many large works in which there have been unquestionably and unavoidably a very considerable number of cases of just the kind of obsolescence he referred to. The fact that the statistics include detailed history of abandoned plants of the Portland, Maine Water District, the Denver Union Water Company, the Pennsylvania Water Company, the Spring Valley Water Company of San Francisco, and the Indianapolis Water Company, besides a number of smaller ones, of itself shows the impossibility of such obsolescence having been avoided in making up the depreciation estimates. The statistics for these cases are very complete and very trustworthy, and they are the sole ones on which I have depended in making up this general estimate.

MR. HATHAWAY.* Mention has been made regarding the appropriation by municipalities of budget moneys for this and that purpose and including water works funds and its purposes.

I am aware that most of the so-called "budget experts" and municipal research theorists do not agree with me in the opinion that a municipally-

* Water Registrar, Springfield, Mass.

owned water works should not properly be included in the city's annual budget.

The listing of any *self-supporting* " *public service enterprise* " in a budget of governmental departments entirely supported by tax levy only results in mystifying and misinforming the tax payers and the general public, in whose minds the " budget " means but one thing, viz.: the apportionment of their *taxes* to the various governmental requirements of the year.

I am sure that every thinking person will admit the truth of this statement upon serious consideration.

One of my good friends at home (a prominent lecturer and a man of more than ordinary intellectual attainments) some years ago said to me, "I see that in my copy of the city's proposed budget for this year appear appropriations for payment of water bonds, for water bond interest, and for water works sinking fund, and you told me a while ago that our water works is a self-supporting enterprise and that none of my taxes are used or needed for such payments! What does it mean?"

I replied that " Of course you, as well as other interested taxpayers, would not be apt to notice that on one of the first pages are listed certain items of estimated revenue from fees, licenses, and other sources, together with only enough of water works revenues to *offset* the so-called *appropriations* for water works purposes; so that such "appropriations" are merely a matter of formality to please the ideas of the budget maker, and actually do not affect the tax levy at all.

Some years ago I suggested to representative of a research bureau in Springfield that any reference to the water works as a *department* be left out of the budget; but that, if desired, special pages might be appended in the back portion of the budget, on which might be listed all self-supporting " public service enterprises " owned and operated by the municipality — such as, (*a*) water works, (*b*) gas plant, (*c*) electric plant, etc. — and under each could be shown the estimated and classified revenues and expenditures of same, as tentatively forecasted by the commissioners, trustees, or other bodies, in charge of such respective enterprises.

I am sure that this method would be far less confusing and more informing to the taxpayers and the general public, and is one of the things I had in mind when I suggested in my paper that a non-political body outside of the local city councils should be appointed to see that a complete separation should be maintained of such public service enterprises from the local political governing bodies, in order that a business administration instead of a political one might clearly show the proper relations of the two to all citizens at all times.

MR. LEONARD METCALF.* (*by letter*). Mr. Sherman's paper is a sound, concise and altogether admirable statement. It reflects the point of view of the banker or critical investor as well as of the engineer and the

*Of Metcalf and Eddy, Consulting Engineers, Boston.

water works operator. It is based upon a careful analysis of sound theory and of reliable records of water works operated intelligently and for long periods of years.

What the writer has to say is dictated rather by the desire to call attention to and emphasize certain facts, well known to the author, than to contribute essentially new ideas to the discussion; and thus to prevent the drawing of erroneous conclusions from some of the statements contained in the author's paper.

A water works plant is essentially a continuing property. Under normal conditions, it never dies unless the community which it serves itself dies. The structures constituting the physical part of the property, on the other hand, have limited lives. They wear out, are outgrown, or become obsolete from one cause or another within varying periods of time. They are replaced or superseded by new units or groups of structures. But there is an average period of existence of the structures, making up the physical plant, and this period is the one to which we refer as the average life of the plant.

Practically, individual groups of structures go out of service, for one reason or another, from time to time, and the investment involved by them must, on the one hand, be retired, repaid or amortized, and the new or superseding structures be covered by new investment; or, on the other hand, the maturing investment must be reinvested in the replacement of the existing or of the new and better adapted structure to do the work of the old structure. The property continues to live and to serve.

What generally happens is that from year to year, after the initial construction of the plant, the plant is extended to meet the growing needs of the community. But with the normal growth of cities in this country of 25 per cent. to 30 per cent. per decade, radical changes, involving major betterments and extensions, substantial replacements and some abandonments have to be made, at intervals of from 10 to 15 years, more or less, which in turn involve extraordinary expenditures. These expenditures are usually financed by bonds, in large measure if not wholly, because they are involved chiefly by the extensions and betterments and because they cover structures designed to meet the requirements of the future 15 or 20 or even 40 and 50 years hence rather than of the present moment.

To the extent that the work involves replacements or abandonments, the old investment must be retired. When retired, these old abandoned structures and the investment upon them are no longer of interest in subsequent valuations of the property.

The author deals, quite properly for simplicity and clearness of conception, with the *entire property* from its inception, rather than with the existing property only — that is with the original property less abandonments — because he is discussing the life of the investment or bonds issued against it, but the difference should be noted, since the usual problem faced in the valuation of water works, in dealing with the depreciation of

any property, is the determination of the depreciation upon the existing property, rather than the depreciation and abandonment upon the entire property from its inception.

The life histories of water works in this country as continuing properties, indicate that the structural property gradually decreases in value despite the increment in value involved by the minor annual betterments, until the average life cycle of the structures is reached, or until the minor betterments approximate the annual rate of depreciation, after which the so-called percentage condition, or full value less fair depreciation allowance of the structural property, remains constant on the average, fluctuating materially only at the more or less periodic times of reconstruction and betterment already referred to.

Thus it has been found that in the smaller, slower growing plants, their condition varies from 90 to 92 per cent., and the accrued depreciation upon existing structures only, often or perhaps generally ranges from 8 to 10 per cent. of the full value of these structures and that the amount of the abandoned property is relatively small, say from one-quarter to one-half in amount of the accrued depreciation upon the existing structures. But in the older plants serving the larger cities, their condition generally varies from 84 per cent. to 88 per cent. and the accrued depreciation from 12 per cent. to 16 per cent., and the amount of the abandonments ranges from one-half to the full amount of the accrued depreciation upon the existing structures.

Upon the thirteen typical plants cited by Mr. Sherman with respect to which full records were available, the accrued depreciation upon existing structures averaged 12.9 per cent; the abandoned structures averaged 7.7 per cent. of the existing structures only; the combined accrued-depreciation-upon-existing-structures and abandoned structures averaged 19.7 per cent. of the value of the combined existing and abandoned structures; and 22 per cent. of the existing structures only.

The conclusions reached by Mr. Sherman appear to be sound and to indicate the principles upon which this Association should stand, and which should be reflected in the laws of this state governing the financing of publicly owned water works.

DISCUSSION.

BY FREDERIC I. WINSLOW.

(By letter.)

[September, 1922.]

Should Water Departments be Merged with other Municipal Departments?

The heart of the question raised by Mr. King's thoughtful paper lies in the vexed and unsettled problem of good city government. As Mr. Sherman states, the trouble bears hardest on the small towns where departments are merged, as the larger cities are compelled to have at least one competent head, or speedily suffer. It was said of the late Richard M. Croker, when he was "Boss" of New York City, that he was always careful to select competent engineers in order to actually prevent other appointees from disgracing his administration of affairs.

But whether the departments are consolidated or kept apart, the allocation of a water department surplus to any other department short of appropriations, will still be a custom.

To make the relation between the water and the other departments equitable, every gallon of water should be paid for to the water department. And the water department should be placed on the same footing as any private utility in the same town, so far as compensation for the use of the streets is concerned,

Along this line for many years after the Boston water works were installed, the revenue fell far short of meeting the expenses, and the city made annual appropriations to meet the deficits. Later when the water works did pay, an attempt was made to reimburse the city for this, but probably the water works is today in debt to the city for the last generation's deficits. So it is not wholly a one-sided question. From the standpoint of the water-works man, the departments should be maintained separately, but from the viewpoint of the municipal expert, all must be consolidated, and this apparent clashing can only be met by placing at the head of the water department a competent head. The subordinates cannot be expected to be above the ordinary level of the public employee in general.

Just now the City Manager idea seems to offer a solution of this question, but this departure appears to be falling into less favor in the eastern portion of the country, although fairly holding its own in the west and south.

Why We Should Inspect Water Works Equipment.

[*September, 1922.*]

While it is a fact that the most disastrous and costly breaks in the water works system are usually due to a cause other than any remediable by any inspection at the foundry, this in no way minimizes the value of insistent inspection. "Eternal inspection is the price of satisfactory castings."

The "rigid bearing" has been responsible for more expensive accidents than any other one cause in the history of the water works of Boston as well as of other large cities.

The moral effect of the mere presence of an inert, even if honest, inspector may well be doubted, especially where the brains of the foundry exceed those of the inspector.

But Mr. Lally's paper is valuable in emphasizing the importance of inspection in all details and no municipality can afford to neglect this feature of water works maintenance.

ROBERT CARTER PITMAN COGGESHALL.

Robert Carter Pitman Coggeshall was born in New Bedford, April 20, 1849. He was the son of Thomas and Caroline (Spooner) Coggeshall, being a direct lineal descendant in the eighth generation of John Coggeshall, who emigrated to this country from the town of Coggeshall, Essex, England, in September 1632, and settled in Roxbury and Boston, and later became one of the founders of the city of Newport, R.I., and at the union of the four towns, Newport, Portsmouth, Providence and Warwick was made the first president of that colony.

Mr. Coggeshall was named for the late Judge Robert Carter Pitman, an intimate friend of his father and mother.

He received a primary education at a private school, entered the Friends Academy at New Bedford and later became a student at the Rensselaer Polytechnic at Troy, N.Y.

He gave up the life of a student in the latter part of 1868 to become a clerk in the New Bedford post office, where his father was postmaster. Five months later he accepted a clerkship at the Bay State Glass Works at East Cambridge. The engineering instinct was in him, however. As a boy it had sought expression, and he had in vacation periods found employment in the surveying department of the Water Works, then first organizing and building the water system. In May, 1872, he returned to New Bedford to become draftsman, surveyor and general assistant to George B. Wheeler then superintendent of the Water Department. In 1877 he was elected city land surveyor. At that time, as the city was small (26 000) this position did not require full time service. Mr. Coggeshall therefore worked into a private engineering practice.

Mr. Coggeshall entered upon the office of superintendent of the New Bedford Water Works and clerk of the Water Board on June 9, 1881, succeeding William B. Sherman. He continued in that position until April 28, 1922, when he was retired on account of ill health. His business life literally covered the entire range of Water Works activities in New Bedford from their very beginning until the date of his retirement, covering the growth of the city from 20 000 to 131 000 population. During all this period he kept the water system well in advance of the growth of the city, showing great foresight in all his operations.

The following resolutions adopted by the Water Board at the time of his retirement express the esteem in which he was held by that Board.

"Whereas, the retirement of Robert C. P. Coggeshall from the offices of superintendent of the New Bedford Water Works and clerk of the Water Board, positions which he has filled with unusual ability for a period extending from 1881 to 1922, gives us an opportunity to express the esteem in which we hold him, and also our appreciation of his long and valued services; therefore be it

"RESOLVED, That we, the members of the Water Board of the city of New Bedford, take pleasure in placing upon the records of the Board our high estimation of his fidelity and ability in the conduct of the affairs of the department.

"The period of his service has been one of constant growth and expansion, including, as it does the time from 1894-1899, when the construction of the enlarged system of water supply was planned and completed.

"In his retirement he leaves behind a record of efficiency and farsightedness, which has few, if any, equals in the municipal service of any community in this commonwealth."

Mr. Coggeshall's life was also very intimately connected with that of this association. He and Mr. Frank E. Hall, then of Worcester, and Horace G. Holden, then of Lowell, met by chance at Lowell in February 1882. During that meeting the idea of forming an association of Water Works men, which had previously been suggested in 1877 by Mr. James W. Lyon but had made no further progress, was revived.

As a result of a great deal of correspondence twenty-one men assembled at Young's Hotel at Boston, April 19, 1882, when the matter was thoroughly discussed and a committee appointed to draft a constitution of by-laws. This constitution was adopted and the association organized June 21, 1882, at Young's Hotel with a membership of twenty-seven. Mr. Coggeshall was elected the first secretary at that meeting and served until 1884. He was president of the association in 1885-86 and again secretary from 1887-1895, when his city work increased to such an extent that it required his whole time, and he reluctantly relinquished this position.

He was the first editor of the JOURNAL when its publication was begun in 1886, and has always been one of the most energetic promoters of the association. He has always contributed liberally to the papers and discussions at the various meetings until within the last few years, when ill health has prevented his attendance. Even the failure of his health could not lessen his interest in the association, as some of the members, who had the pleasure of calling upon him during the recent convention in New Bedford, can testify.

On February 10, 1915, he was made an honorary member of this association.

He was also a member of the American Water Works Association, the Boston Society of Civil Engineers and the Connecticut Society of Civil Engineers.

He was very much interested in the Masonic fraternity, being a member of Star in the East Lodge A.F.& A.M., Adoniram R.A. Chapter, New Bedford Council R. & S.M., and Sutton Commandery K.T. He was also a member of Acushnet Lodge I.O.O.F. and the New Bedford Encampment. He was an earnest and active member of the First Congregational (Unitarian) Society where for years he rendered valuable service as a member of various committees. He was a member of the Wamsutta and Brook's Clubs as well as a trustee of the New Bedford Five Cent Savings Bank.

Mr. Coggeshall married Ledora Jenny on December 21, 1875. She died December 15, 1885. The two children of this marriage, Robert F an electrical engineer in the employ of the General Electric Co., at Schenectady, N. Y., and Miss Helen R. of New Bedford are both living.

On April 29, 1890, he married Sarah Wall Almy of New Bedford, who also survives him.

He was an honor to this Association, and as a public official he always stood out as an example to the organization for his faithful, conscientious performance of duty.

His able counsel and genial smile will be greatly missed not only at the meetings of this association, but in many of the activites of his native city.

Respectfully submitted,

S. H. Taylor,
C. E. Davis,
Robert J. Thomas.

CHARLES E. PEIRCE.

Charles E. Peirce, son of Chauncey and Ellen M. Peirce, was born in Lincoln, R. I., June 8, 1848. In 1858 his parents moved to East Providence, R. I., where he continued to reside until his death on January 18, 1922.

On April 4, 1865, when scarcely eighteen years old, Mr. Peirce enlisted in Company H, Third Battalion, 15th U. S. Infantry, seeing service at Fort Adams, Mobile and Lookout Mountain before being discharged April 4, 1868. After his discharge from the Army his interest in military affairs was transferred to the State Militia and in 1884 he served as Sergeant Major, First Battalion of Cavalry. In later years he was very active in affairs of the G. A. R. and at the time of his death was Senior Vice-Commander, Department of Rhode Island, G. A. R.

In 1874, Mr. Peirce entered business as a contractor, mason and builder. In 1893, he constructed the pumping station of the East Providence Water Company and upon the completion of the water works in 1895, was elected superintendent, which position he continued to fill until he passed away.

On July 30, 1873, Mr. Peirce was married to Mary Wagner of Sharon Springs, N. Y. One son, Chauncey Peirce, who died in 1885 at the age of eleven, was the result of this union. Saddened by the death of his wife in 1912 and with no immediate family Mr. Peirce sought consolation and companionship in various fraternal organizations with which he was affiliated. He was a member of Redwood Lodge No. 35, A. F. & A. M., Solomon's Lodge of Perfection, R. I. Council Princes of Jerusalem, R. I.

Chapter of Rose Croix and R. I. Consistory, Reliance Lodge No. 34, I. O. O. F., and Howard Lodge No. 12, Knights of Pythias, of which latter body he was Past Grand Chancellor.

In civic affairs Mr. Peirce also took an active interest, serving at various times as chief of police, as a member of the Town Committee and as a member of the Town Council of his home town. Always active in matters pertaining to the conservation of bird and game life, in 1911 he was appointed a member of the State Bird Commission on which he served until 1920.

Elected to membership in the New England Water Works Association September 14, 1887, and a regular attendant at its meetings for nearly thirty-five years, his wise counsel, his never failing courtesy and helpful service brought to him a wide circle of friends among water works men. In his death the Association, the community and the State lose a worker for all that was best in many important human interests.

STEPHEN DE M. GAGE,
ALBERT E. DICKERMAN,
Committee.

PROCEEDINGS.

NOVEMBER MEETING.

BOSTON CITY CLUB,
Tuesday, November 14, 1922.

The President, Frank A. Barbour, in the chair.

The following were duly elected members of the Association:—

Active: John L. Morton, Water Commissioner, Plymouth, Mass.; Richard Sigfred Holmgren, Lynn, Mass. — 2.

Associate: Chase Metal Works, Waterbury, Conn., Brass Manufacturers; Fields Point Manufacturing Company, Providence, R. I., Manufacturers of Liquid Lime Bleach, Liquid Caustic Soda and Liquid Chlorine. — 2.

Dr. Richard Moldenke, of Watchung, N. J., gave a talk on "Some Engineering Aspects of Cast-Iron."

A paper on "Tars, New and Old," illustrated with the steropticon, was read by Mr. S. R. Church, Chemist and Manager of Oil and Tar Division, The Barrett Company, New York City.

Moving pictures were then exhibited showing the making of pipe by the sand method, and also showing the centrifugal process of casting pipe at the new plant of the United States Cast-Iron Pipe and Foundry Company, Birmingham, Ala.

MR. CHARLES W. SHERMAN. Mr. President, we have experienced a most remarkable meeting of this Association, and as a very slight expression of our appreciation of what has been given to us here I move a rising vote of thanks to Dr. Moldenke, to Mr. Church, and to the United States Cast-Iron Pipe and Foundry Company.

(The motion was duly seconded and unanimously carried by a rising vote.)

(*Adjourned.*)

NORTHEASTERN UNIVERSITY LIBRARIES
3 9358 00859681 6

NORTHEASTERN UNIVERSITY LIBRARIES
3 9358 00859681 6